SCIENTIFIC PRESERVATION OF FOOD

by

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INTRODUCTION

Constituent Element of Foods—Natural Cycles of Synthesis and Decomposition—Definition of "Food Preservation"—Development of the Art and Its Influence on Civilization.

To arrive at a satisfactory definition of the term "Food Preservation" we must first go back to the basic elements of all foods—carbon, nitrogen, hydrogen and oxygen. We are all familiar with these elements in their simplest forms in every-day life; we recognize carbon as coal, graphite and—in pure crystals—diamond. Nitrogen exists in enormous quantities in the air, comprising about four-fifths of its volume. Hydrogen and oxygen exist in combination as water. Oxygen of course is the super-important constituent of the air we breathe. Hydrogen is not found by itself in the lower air. On account of its lightness it escapes into space almost as fast as released by natural chemical processes.

Now these four elements are the prime ingredients from which nature has fashioned every living thing. Therefore these same elements must be used to maintain the life of every living thing. Nature uses other elements too in her building operations, all of which are exceedingly important in their places, but for the present we need consider only carbon, hydrogen, nitrogen and oxygen.

In the age-long building processes of nature each of

these elements goes through definite transformations known as cycles. In these cycles they go from one chemical combination to another, until finally they revert to their original form, only to repeat the cycle again and again. Some cycles may be finished in a very short time; others may require hundreds of centuries. As an illustration let us take a possible nitrogen cycle. We start with an atom of nitrogen in the air. It is caused to unite with oxygen by means of a flash of lightning. It is washed to earth by rain and becomes part of the soil. It is taken from the soil by a plant and upon the decomposition of the plant is released as ammonia and washed by rain into the sea. It then may pass through the stages of microscopic sea plant life, a fish, and a seabird, to a guano deposit on some arid coast. From here it may be mined and refined as sodium nitrate and finally made into an explosive. When the explosive is set off our nitrogen atom is instantly thrown back to its original state as a constituent of the air, ready to start the next cycle.

All four of the elements have cycles of the same general character. By means of these cycles—with the help of the sun's energy—all life is built up and destroyed.

All the food of mankind, as well as that of all animal life, is the product of some process of life. We are forced to maintain our own life processes by the consumption of products of other living things. These food substances which man harvests, collects and transports for his support and maintainance are of course subject to the natural cyclic laws which we have just discussed. They are constantly coming under the influence of natural

causes of decomposition. Our stored grains may be eaten by rats or infested with weevil. Our cured meats may be attacked by insect parasites or be changed by internal chemical reactions hastened by storage at high temperatures. Fruits and vegetables may be overgrown with molds or attacked by yeasts and bacteria.

We are now ready to define "Food Preservation" as the man-directed interruption of the natural cycles of evolution and decomposition of food substances. This may appear to be a very round-about way of arriving at the definition of a term that seems to define itself. In attempting to preserve foods, however, we are flying in the face of some of nature's most zealously enforced laws. Opposing nature is always a difficult undertaking and it is felt that the stronger these facts are impressed at the beginning, the better for our understanding of future difficulties.

It is unnecessary to go very far back into history in order to study the methods of development of Food Preservation. Since we have peoples of all gradations of civilization living in all climates from the equator nearly to the poles, we can gather our information first hand.

There can be little doubt but that the first man procured his food supply by foraging in the jungle with little thought of the morrow. It is also probable that the first food stored was in the form of seeds and nuts, which were subject to little damage except from animals and insects. The storage of such food is carried on instinctively by animals and even by insects. Flesh foods were probably not stored to any great extent, although drying, salting and smoking were undoubtedly developed

at a very early date. The practice of some tribes of following wild or semi-domesticated animals from place to place may be classed as a type of food preservation.

The storage of grains and the drying, salting and smoking of fish and flesh foods were the principal methods of food preservation up to the beginning of the nineteenth century. They are still the most important from the point of view of quantity and value of products treated. The real victories over nature, however, are embodied in such discoveries as artificial refrigeration, the bacteriological discoveries of Pasteur, the development of the tin can and many others equally important.

The development of new methods of preservation and the improvement of old ones have had an immeasurable influence on the advance of civilization. Ocean navigation has been immensely extended and the development of large cities has been made practical on account of improvement in methods of food preservation. Our entire book could easily and perhaps profitably be devoted to this fertile subject but we can occupy ourselves to better advantage by discussing the methods evolved by man to preserve his food supply against natural agencies of destruction.

PREFACE

For the past twelve years the writer has been engaged in applying the principles of Chemistry and Bacteriology to the problems of the food manufacturing industry. This experience has included extensive analytical work, solution of spoilage problems, and finally the creation of new products and processes. He soon found that, while analytical methods had been thoroughly worked out and collected, the constructive side of the industry had been greatly neglected.

In developing new products and processes he was obliged to proceed by the old-fashioned method of trial and error, and many were the trials and only few less the errors. Gradually, as principles were recognized and filed away mentally, the subject of Food Preservation began to present itself as a whole and the idea of this book was born.

In planning the book it seemed logical to first classify the foods, then the causes of spoilage, and finally the methods of preservation. A chapter on Food Containers was added on account of the very great influence of the container on the keeping qualities of foods. An effort has been made to eliminate technical language as much as possible, and where technical words are necessary they have usually been defined. Therefore the writer hopes the contents of this book will be of interest

to the non-technical man, as well as to the technologists of the food industries.

Material has been accumulated from so many sources that it is impracticable to acknowledge the help of each of the many individuals who have given conscious or unconscious assistance in the preparation of this work. However, the writer wishes to express here his appreciation of the kindly assistance and encouragement he has received from the many scientists and technologists with whom he has had the pleasure of working.

Thomas M. Rector

30 Church Street, New York
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CHAPTER I

CLASSES OF FOODS

Principal Constituents of Foods—Proteins—Carbohydrates—Fats—Mineral Salts—Organic Acids and Bases—Water—Classes of Foods with Reference to Origin—Cereals—Legumes—Nuts and Oil-Bearing Seeds—"Vegetables"—Fruits—Edible Fungi—Flesh Foods—Domesticated and Wild Animals—Birds—Fish—Crustaceans—Milk and Its By-products—Eggs

It would be possible to write this book without mentioning specific foods. This could be done for the reason that a few simple laws control the matter of whether a food spoils or keeps under the conditions of storage. It will be easier, however, to fix these laws in mind if we can refer to the different classes of foods as illustrations as we discuss them.

We have already made note of the fact that the essential food elements are carbon, hydrogen, oxygen and nitrogen, and that these elements combine to form the more or less complex substances which make up the greater proportion of all foods. These compounds have been classed rather crudely as follows:

1. Proteins
2. Carbohydrates
3. Fats

In addition to the compounds included in these classes,

all foods contain in greater or less degree mineral salts, organic acids and bases and other compounds. Many of the minor ingredients of foods are of greater importance from the standpoint of preservation than the three main groups.

The term Protein as used here is intended to cover the nitrogen containing substances in foods. Proteins contain all the four elements and are the essential body building constituents of foods. They occur in both animal and vegetable foods but proteins of animal origin are more readily digested by man and when digested are more readily used in the building processes. Animal proteins are known as "complete proteins" because they contain all the subsidiary compounds or amino acids found in human flesh. We cannot always build flesh from vegetable proteins for the same reason that we cannot make a complete picture from half the pieces of a jigsaw puzzle. From two identical puzzles, from both of which pieces were missing, we might build a complete picture. The same analogy holds true for incomplete proteins from different sources combined in the diet.

Carbohydrates contain carbon, hydrogen and oxygen. The hydrogen and oxygen are combined in the same proportion that they exist in water, two atoms of hydrogen to one of oxygen. Carbohydrates are literally burned in the body to produce energy and when not needed for this purpose are often stored as fat. Sugar and starch, the two principal carbohydrates, are, in quantity, the most important of all food constituents.

Fats are also compounds of carbon, hydrogen and oxygen, but in them the oxygen plays a very minor role.

Fats are the richest of all energy foods, having twice the heating value of proteins and carbohydrates when digested.

Mineral salts in foods are made use of in the body as material for the formation of bones and teeth, as important constituents of flesh and blood and in other ways, many of which have been only guessed at by physiologists. The principal mineral elements found in foods are sodium, potassium, calcium, magnesium, silica, iron, aluminum, sulphur, chlorine and phosphorus. Other elements are also found in lesser amounts. The same mineral elements, as well as the organic ones, are found in both animal and vegetable foods. This is not at all strange when we consider that all animal foods are built up directly or indirectly from plant life.

Organic acids and bases as well as acid and basic salts are present in almost all foods in small amounts. Though small in quantity these substances have a great deal of influence on preservation methods. Acids and acid salts are found in almost all fruits and many vegetables. Basic substances are confined principally to animal foods although some vegetables, asparagus for instance, contain them. From our point of view these substances are chiefly of interest on account of their influence on the growth of micro-organisms of spoilage.

Another food constituent yet remains which is of more importance to us in many ways than any we have discussed. This constituent is water. There are no problems of food preservation in which we do not have to consider it. No digestion process, whether of animal, plant or micro-organism can go on without it and water

is concerned in some way with almost every deteriorating chemical change in food. Water is found in all our foods, the amount being least in highly refined foods, such as sugar and fats and most in fresh fruits and vegetables.

We have now touched briefly upon the important classes of compounds that go to make up our foods. We are now ready to classify the foods themselves in their relation to their constituent compounds. It is again emphasized that this classification has no direct bearing on the preservation of the foods. Preservation methods are based entirely on other considerations than the origin of food.

Foods of plant origin:

1. Cereals
2. Legumes
3. Nuts
4. "Vegetables"
5. Fruits
6. Fungi

Foods of animal origin:

1. Flesh Foods
2. Dairy Products
3. Eggs

Prepared or manufactured foods.

This is not intended as a fixed classification of foods but merely as means of showing the relationship, or rather the lack of close relationship between the conventional methods of classing foods and the system of

food preservation that we are trying to build up. There is nothing to be gained in arguing that a peanut is a legume or that a tomato is a fruit and not a vegetable. Food preservation methods do not require such classification. However, it will be helpful for us to fix in mind the salient characteristics of each class of food.

Cereals form a large proportion of the foodstuffs of mankind. They are composed essentially of carbohydrates and proteins. Ordinarily cereals contain from sixty-five to eighty percent starch (carbohydrate), very little fatty matter and no large amount of mineral salts. Being easily air dried and having little ability to absorb moisture from the air under ordinary conditions, cereals are very easily preserved in a natural state. It is common practice to hold wheat for as long as two years. Wheat has been recently found in good condition in ancient Egyptian tombs.

The principal cereals are wheat, rice, maize, oats, rye, barley and millet. There are many others of minor importance. Wheat is the predominant cereal of the temperate zone. Rice holds forth in the Orient as the principal food of half the human race. Maize or Indian corn is used to a great extent as human food but is even more important as a food for domestic animals. Used in this way it is really a sort of secondary food, man delegating to the animal the time-consuming job of building flesh out of incomplete proteins. Oats, rye and barley are temperate zone cereals, secondary in importance to wheat and maize. Millet is of importance in the Orient, especially China.

Cereals reach the ultimate consumer in many forms.

We have all stages of development before us from the savage who pounds grain to a powder in a crude mortar to the modern highly efficient breakfast food factory or the even more complicated cracker and biscuit factory.

Our second class of foods, the legumes are widely distributed and very important as a class, even though they do not approach the cereals in quantity. Legumes include beans, peas, clovers, alfalfa, peanuts and many others of importance. Some legumes contain all the common food substances in surprisingly well balanced amounts. Others are deficient in fats. The peanut and the soy bean, however, are among our most important sources of vegetable oils and grow more important yearly in this respect.

In addition to this use peanuts are extensively eaten after roasting or frying in oil and as constituents of confectionery. Various kinds of beans and peas are dried and handled like cereals. Other forms are used as green vegetables, both shelled and in the pod.

String beans and lima beans are extensively canned. The small white "navy" bean and some other dried beans are also canned with sauces after soaking in water.

Clover, alfalfa, soy beans and certain kinds of peas are grown extensively as forage for domestic animals. It is worthy of note that legumes have the power to harbor certain bacteria in their roots which enrich the soil by their marvelous ability to convert the nitrogen of the air into plant food.

Nuts and seeds are classed together on account of the general similarity of their composition and use. They are in general notable for their high oil content. They

are also uniformly high in protein. All contain fair amounts of carbohydrates, in some cases as starch, in others as sugars and in still others as cellulose and other carbohydrates not at all well known.

This class of foods finds extensive use as a source of vegetable oils, as an important constituent of confectionery and bakery products and directly as table delicacies.

Among the important oil bearing nuts and seeds might be mentioned coconuts, almonds, cottonseed, linseed, rape seed, mustard seed, sesame seed, poppyseed and sunflower seed. All of these products are very important sources of vegetable oils. After pressing the residual cake or meal is generally used as cattle food. Coconuts and almonds of course have many other uses. Coconuts, in fact, are a staple food among untold millions of tropical peoples and desiccated coconut has lately taken rank as a staple product in the United States.

Coconuts, almonds, walnuts, pecans, Brazil nuts, filberts and pistachio nuts are all extensively used in confectionery and bakery products. The use of nuts is being rapidly extended in all fields and the end of this extension is difficult to see.

On account of their high oil content nuts and seeds are liable to many forms of decomposition to which cereals and oil free legumes are not subject. These changes will be considered later.

The term "vegetable" is a very unsatisfactory one. As ordinarily used it covers many foods which would be more properly included in other classes. For instance, tomatoes have more of the characteristics of fruits than

of most vegetables and string beans are certainly legumes. We have already agreed, however, that distinctions of this kind need not be made here. Therefore we must be satisfied with the rather loose definition that "vegetables" are the edible roots, leaves, fruits, tubers and shoots of plants, principally annuals, which man has found by experience to be suitable for food purpose.

In the fresh state vegetables are characterized by a very high water content, from 75 to 95 percent. The solid portion contains fairly well balanced proportions of carbohydrates and proteins and liberal quantities of mineral salts and other food accessories. Fat is almost entirely absent.

Some vegetable foods that hold important places in our diet are potatoes, tomatoes, green peas, cabbage, sweet potatoes and string beans. In spite of wide differences in appearance, flavor and other characteristics these foods are susceptible, with trifling exceptions, to the same agencies of change and spoilage and therefore respond to the same agencies of preservation.

Methods of handling vegetables have improved to such a great extent that many of them can be obtained in a fresh state all year around. Some of them are successfully preserved by dehydration and most of them are extensively canned. Methods of handling and preservation will later be discussed in detail.

Fruits form a class that is comparatively easy to characterize. They are uniformly high in water, organic acids and mineral salts. Their solid matter is chiefly sugar and fiber. Very little fat or protein is included in their composition.

Apples, pears, plums, cherries, peaches, grapes, apricots and several varieties of berries are all important fruits of the temperate zones. Oranges, lemons, the mango, the pomelo or grape fruit, bananas, pineapples and the bread fruit are equally important in tropical and semi-tropical regions. The olive is also worthy of mention as one of the few fruits that contains oil in appreciable quantity.

The work of the plant breeders and the growing skill of food preservers are making fruits more and more common as constituents of our diets.

By reason of their high water content and the ease with which they are mechanically injured fruits present many difficult problems to the food preserver. Most of them, however, are fast melting away before the advance of scientific methods.

The edible fungi are not of very great importance as direct foods. They constitute a distinct class however and must be treated as such. Fungi are often allowed to grow on foods during their processes of manufacture for the sake of the changes that they produce. Yeast is grown in dough for the purpose of leavening it or making it "light." Molds are grown on certain cheeses for the flavor that is developed. The Chinese and Japanese use certain molds to make soluble some of the ingredients of "soya" sauce. These, however, are not primarily fungus foods.

Yeast and extracts made from it has lately attained some prominence as food of itself. This has been occasioned by the discovery of vitamines and their importance in the diet. Yeast has been found to contain one of the vitamines in exceptionally large amounts.

Mushrooms are, of course, the most outstanding example of fungi as food. These fungi have become important foods in some countries where they are found in a wild state. Now that they are cultivated in pure cultures like yeast it is easy to foresee the rapid development of their use.

It is rather strange to find that delicate fungi, such as yeasts and mushrooms, yield to the same preservation methods used on the common foods. If their individual peculiarities are taken into account, however, there is found to be not the slightest difference in general behavior.

Flesh Foods.—The inhabitants of the temperate and frigid regions of the earth soon learned that it was easier to let animals collect their food for them, and store it as flesh than to spend their time collecting the difficultly digestible vegetation themselves. This discovery led to the formation of the nomadic habits of the Aryan races of the North and the experience gained in following and killing their food-animals undoubtedly had a great deal to do with their becoming the dominant race of the earth. The domestication of food animals was the next logical step. It is worthy of note here that with all the inventiveness of the last century no great success has been made of domesticating any new animals. Great strides have been made, however, in breeding animals for superior food producing qualities and in spreading these well bred animals wherever climatic conditions were suitable.

At first there was probably very little attempt to preserve flesh foods after the animals were killed. The

habits of savages of today offer evidence of this. Salting, drying and smoking were developments that came later, the methods no doubt being discovered by accident. The observation was undoubtedly made that food kept well in winter but little effort was made to use this observation practically. It may be quite a blow to our self-esteem to find that these four basic methods are the backbone of our flesh-food preservation methods today.

In their raw state flesh foods are much more uniform in composition than vegetable foods. This holds true whether the flesh is obtained from mammal, fowl, reptile or fish. All flesh foods are predominantly protein foods. Carbohydrates are almost entirely absent. Fat is present to a greater or less extent depending on the condition of the animal when killed. Fat in animals as well as in our own bodies, is provided by nature to act as a buffer against starvation. The amount of fat in flesh foods therefore, depends on whether the animal, from which it was obtained has had plenty of food or not.

Mineral salts are present in all flesh foods of the same kinds and in about the same amounts as those contained in our own bodies.

Among domestic mammals cattle, sheep and hogs are by far the most important. A great deal of horse meat is consumed in Europe. The reindeer is important in the Arctic regions and is being introduced into temperate zone markets wherever there is an excess.

Wild mammals are also of some importance although their numbers are undoubtedly decreasing as a whole. Various species of the rabbit and deer families are economically the most important of these for food purposes.

The domesticated birds are very important sources of food in all countries. Many of them are able to live on almost any kind of food and thrive in close confinement. They are therefore almost ideal as a source of flesh food for thickly populated countries. The Chinese take every possible advantage of the characteristics of domesticated fowls, making it possible to support a population of a half billion on an area not much larger than the United States. The hen, duck, goose and to a lesser extent the turkey are all exceedingly important as sources of food for the entire world. The hen, in particular, is esteemed by all races from the most savage to the most civilized.

The reptiles furnish very little food for mankind, particularly civilized mankind. Turtles and frogs are eaten and esteemed a delicacy, but they are of little interest from the standpoint of food preservation.

Fish have furnished food for man for untold generations. Even to this day they are the principal food of millions. The herring, cod and salmon are the most important if we judge by quantity and value. The sardine, mackerel, tuna, halibut, haddock and pollack are also of great commercial importance. The inedible fish are very few. Many fish, highly valued as food in some parts of the world, are discarded as useless in others.

Crustaceans or shellfish form another class of flesh foods of great variety and vast distribution. Almost every country has its favorite species of oyster, clam, lobster or crab. Most of the crustaceans are strictly water organisms but the French have made quite an

important food item of the snail, which is a land crustacean.

We have made no distinction in the characteristics of the flesh foods from the different classes of animal life because there are no broad distinctions to be made. There are certain minor distinctions, such as differences in the melting point of fats from warm and cold blood of animals and differences in the action of proteins under heat that deserve mention when we discuss specific preservation methods but have no place here. Flesh foods as a class contain from sixty to ninety percent of water and are comparatively free of substances, such as acids and acid salts, which might act as retardents of spoilage by micro-organisms. Therefore, they fall into the class of foods that must be protected from practically every agency of spoilage.

Milk is in a class by itself by reason of being the only complete balance of food ready for consumption in its original state. It contains protein in plenty and of the highest quality. The proteins of milk are "complete." They can rebuild any worn out tissue of our bodies. Carbohydrates and fat are present to supply our energy needs. Milk also contains the food accessories—vitamines and mineral salts. Besides being a perfect food in itself, milk has been made for ages into other important products. The manufacture of butter and the innumerable varieties of cheeses are among the oldest arts that man has inherited. Milk is also converted by several methods of fermentation into beverages some of which are used very widely.

Milk is being dried more and more extensively.

Enormous quantities are also being evaporated partially and canned with or without sugar.

Milk production, handling and sanitation are of basic importance, especially to inhabitants of cities and great progress has been made in this respect in the last twenty years.

Eggs of birds, fish and reptiles may be classed together in this discussion. All of them are protein and fat foods of the highest order. If eggs contained carbohydrates in a balanced amount they would be worthy of classification with milk. Eggs differ from milk inasmuch as they contain the necessary elements for creating a living organism while milk is intended to maintain a living organism after birth, supplying it with energy as well as with replacement material for worn out tissue cells.

The eggs of birds in general, and domesticated birds in particular, are the most important foods of this class. Fish eggs are of minor importance while those of reptiles rarely enter commerce. The eggs of the hen are a staple food all over the world. In Oriental countries duck eggs are of importance. The eggs of the guinea fowl are entering commerce in increasing quantities. In Japan and China quail and pheasants are domesticated for their eggs.

Eggs are prepared for food in innumerable ways, both alone and in combination with other foods. They are stored in enormous numbers in the shell. Large quantities are exported from China, either frozen or dried and used in bakery products and in other manufactured foods.

Fish eggs or fish roe comes into the market salted,

frozen, smoked and canned as well as fresh or refrigerated in some way. Sturgeon roe prepared as caviar is considered a delicacy. Shad roe and the roe of river herring are of commercial importance in the United States. The roe of other fish is used locally wherever obtainable.

CHAPTER II

MANUFACTURED AND REFINED FOODS

Definition and Classification—Sugars—Starches—Fats and Oils—Bakery Products—Confectionery—Non-alcoholic Beverages—Fermented and Distilled Liquors—Condiments—Beverage Substances.

Manufactured Foods

We have discussed, in a very sketchy manner, the vegetable and animal foods and have divided them roughly into classes to help in discussing them further. A century ago these two classes would have covered practically every commercial food product. Now we must consider a great new class of foods, derived, of course, from both the vegetable and animal classes, but so inextricably mixed and changed in character that they cannot be classed with either of them. For want of a more descriptive name, we shall call them "manufactured foods."

As in the other classes of foods we shall have considerable difficulty keeping our classes and sub-classes well defined. This is of little moment, however, because manufactured foods, no matter what the source of raw materials, are subject to the identical laws that govern the preservation of simple vegetable and animal foods.

Manufactured foods may be very simple in composition though derived through complicated manufacturing operations. They are often very complex in composi-

tion, many of them being mixtures of a great many foods of widely different origins. We can subdivide manufactured foods into some rather clean cut divisions but a complete sub-division is out of the question. Some of the more important sub-divisions are the following:

Sugars	Confectionery
Starches	Beverages (Non-alcoholic)
Edible Oils and Fats	Distilled Liquors
Bakery Products	Fermented Liquors

It will be noted that the sugars and the fats are very important ingredients in some of the other classes named, in addition to being important manufactured foods in themselves.

The sugars form a large proportion of the diet of every race whether extracted from their sources and purified or eaten as part of the original vegetable tissue.

By far the most important sugar is sucrose, or cane sugar. This sugar is the valuable constituent of sugar cane, which can be grown in parts of most low-lying tropical countries, and is extracted also in enormous quantities from the sugar beet in the temperate zones. Sucrose is found in lesser quantities in many other sources among which may be mentioned the sugar maple tree, juices of certain palms, coconut milk, etc. Refined cane or beet sugar is one of the purest food products that comes to our tables, having less than one-tenth of one per cent of foreign constituents.

The next group of sugars in importance are those derived from starches. These are dextrose, maltose and the dextrines. The dextrines are intermediary products

between the sugars and starches but are here classed with the sugars for convenience. Commercially starches are converted into sugars by two processes. The older of the two is known as malting. The conversion of the starch as accomplished by the action of ferments from partially sprouted grains. The malting process is used extensively for the product of malt sugars, syrups and extracts and as a preliminary step in the production of distilled and fermented liquors. A process of more recent development is the conversion of the starches to sugars by heating with small amounts of acids and afterwards neutralizing the acids. By this method the products which we know as "corn syrup," "cerelose," "glucose," etc., are produced.

These sugars whether made by malting or by the acid conversion process consist essentially of dextrose, maltose and dextrines in widely varying proportions. All of them are finding increasing application in the home and in the manufactured food industry.

Fats and Oils.—Purified fats and oils, both from vegetable and animal sources, are also finding greatly extended uses as food substances. Increased skill in extraction and refining these products is largely responsible for this. A few years ago the extraction and purification of oils and fats were operations carried on crudely in the home and on the farm. Butter making and the extraction of animal fats for food and lighting purposes are among the oldest of the food manufacturing arts. Olive oil and coconut oil are vegetable oils whose lineage is also very ancient. From these small beginnings we can follow the progress of the industry to the present

day factory where oils and oil bearing substances are collected from all quarters of the globe and extracted, treated and refined to an almost unbelievable degree of purity and converted into such products as cooking oils, salad oils, vegetable and animal margarines and an endless variety of subsidiary products.

Among animal fats the most important are beef fat or tallow, and hog fat or lard. The fat from other animals is extracted to a greater or less extent but very little of it finds its way into our food supplies.

Beef tallow is very little used as food in its original state but great quantities of it are separated by chilling and pressing into "oleo oil" and "stearine" and the "oleo oil" used in making "oleomargarine. Lard is sometimes given the same treatment, but for entirely different purposes, lard oil having important uses in the arts.

Butter fat is of course the most important animal fat. Being designed by nature as a food for mammals it is almost the ideal food fat for man. Butter is not only important as a source of energy but also for the food auxiliaries or "vitamines" that it contains. With the exception of butter fat there seems to be a tendency to give up animal fats as foods. This is quite the logical thing to expect. The vegetable oils are identical in energy value with the animal fats and are inferior to butter fat only in being deficient in vitamines. With the perfection of production and refining methods vegetable oils will force the other animal fats into the background because they are their equal in every respect and are cheaper to make. Animal foods will always hold their

own as a source of protein. The easily digested and assimilated "complete" proteins of flesh foods cannot be duplicated in the vegetable kingdom. A certain amount of animal fats will therefore be produced as by-products.

The sources of vegetable oils have been discussed under the heading of oil-bearing seeds. The great headway made by the vegetable oil industry in the last few years has been due more to the development of oil extraction machinery and refining methods than to the discovery of new sources of supply. With modern methods of extraction oil can be obtained from sources that were not considered even fifty years ago.

Corn oil, which is present in corn or maize to the extent of only one or two per cent, has become one of our most widely used edible oils by the application of constructive technical research. Cottonseed, formerly a nuisance has been made to yield an enormous quantity of a most satisfactory food oil by the improvement of refining and deodorizing methods.

Coconut oil also deserves mention because of the enormous expansion of its use in the last twenty-five years. Coconuts grow profusely in all tropical countries near the sea-coast. They are therefore easily accessible for transportation. Their high oil content, seventy percent on the basis of dry coconut meat, makes the extraction of the oil comparatively easy. Olive oil, rape seed oil, soy bean oil, sunflower oil, peanut oil, and palm oil are commercially of great importance in the localities where they are produced and to a greater or less extent in other lands. Olive oil is the staple oil in the Mediterranean District, soy bean oil in parts of China, and sunflower

oil in Russia. Peanut oil, rape seed oil and the palm oils are standard articles of commerce over the greater part of the world.

Starches.—We have discussed the importance of the starches as they exist in cereal foods, roots, etc. Most of the starch that is consumed as food is eaten without extraction from its source and purification. Enough starches are extracted and purified, however, to warrant consideration of their characteristics as food stuffs.

The principal sources of commercial starches are corn or maize, potatoes, rice, tapioca, arrowroot and the cereal grains. Starches in general are extracted by grinding the raw material in water, separating a milky liquid and allowing the starch to separate from the liquid by settling. The crude starch thus obtained is purified by washing and finally dried at a low temperature to avoid gelatinizing or cooking.

Pure starch is one hundred percent carbohydrate and can be classed with the sugars for food value. Starches are popularly supposed to be difficult to digest but there is very little evidence to support this belief. On the contrary there is ample evidence to show that properly cooked starches are exceptionally easy to digest.

Starches are seldom eaten as such but are extensively used as constituents of other manufactured foods. Their keeping qualities when so used depend on the composition and treatment of the finished food. Pure dry starches are not affected by the common causes of decomposition as long as they remain dry. They are free from most chemical changes that affect dry products. In this respect they resemble the sugars.

Bakery Products.—The bakery is probably the world's first food manufacturing plant. The present gigantic development of the baking industry is but a natural growth of a business that fills a basic need of our civilization. Every people, whether savage or ultra-civilized, has its more or less standardized bread. The grain may be pounded into a powder in a crude stone mortar or ground into white patent flour in a modern mill, but the final product is—bread.

The basic cereal for bread is wheat over almost the entire civilized world. Each nation has its secondary bread-making cereals which are used for variety and in emergencies when wheat is not obtainable. Other wheat substitutes are found outside the cereal class such as potato flour, arrowroot, chestnuts, peanut flour, soya bean flour and others. Wheat remains supreme, however, because of its stability in storage and transportation, its world-wide distribution, and the presence of a substance called gluten, which makes wheat flour superior to all others for the bread making processes.

We are accustomed to think of flour as the only constituent of bread worth considering. Upon investigation, however, we find that the modern bakery product contains substantial quantities of fats, sugars, yeast, salt and other special ingredients. The fat or "shortening" is obtained from both animal and vegetable sources. Sugars may be either from cane or beets or from grain in the form of glucose or malt extract. The growing of pure yeast for bread making is a large business in itself with alcohol and vinegar as important by-products. Special kinds of bread are flavored with poppy, anise

and other seeds. Each nationality has its favorite bread flavor or flavors.

Besides taking over a large percentage of the bread baking of civilized countries, the baking industry has gone very largely into the baking of cakes and pastry, formerly an exclusive kitchen function. Enormous firms have been built up for the baking of small cakes and crackers alone. Other firms specialize in the production of pies and other pastry, large cakes in packages, etc. These firms use flour, baking fats, sugar, eggs, milk products, chocolate, nuts, spices, and flavorings in very large amounts and in endless combinations and the preservation of final products from the factory to the consumer is of the greatest importance to the student of food preservation.

Confectionery.—The term "confectionery" as used here is almost synonymous with "candy." By stretching the term, we might put in many of the sweet cakes which we have classed under bakery products; also ice cream and its variations.

The main constituent of candies is, of course, sugar, with glucose or corn sugar a close second. Chocolate is probably third. Chocolate candies are essentially different from ordinary sugar candies. Instead of depending on the binding qualities of boiled sugar solutions, chocolate candies are dependent on the cocoa butter to hold them together. These two classes of candies must be considered very differently from the standpoint of food preservation principles, sugar candy being treated as a carbohydrate and chocolate candy as a fatty product.

Non-alcoholic beverages or "soft drinks" form another

class of manufactured foods that is of very recent development. These beverages are of two different classes, one having a base of malted grain, the other a base of cane sugar. The malted grain drinks are usually unflavored except for the natural flavor of the malted and fermented grain and the bitter principles of hops. The sugared drinks contain fruit and spice flavors, both natural and artificial, and combinations of natural and synthetic oils which have been found pleasing to the public taste.

Fermented and Distilled Liquors.—Fermented and distilled liquors may be considered together, since one is derived from the other. Fermented liquors are made by the action of yeast on suitably prepared solutions containing sugars. The two main classes of fermented liquors are made from grain and fruits. Barley, rye, maize and—in the Orient—rice, are all important bases for fermented grain drinks. Grapes are the most important among the fermented fruit drink bases. Almost any fruit may be used for this purpose. In various countries figs, dates, apples, peaches and cherries are used with more or less satisfactory results. Grain drinks are known under various names such as beer, ale, porter, etc. Fermented drinks from fruits are generally known as wines. By distillation of fermented grain liquors, a liquid high in alcohol is obtained. Upon ageing this liquid in charred barrels, whiskey is obtained. The methods of distillation and the kind of grain used vary in different countries, making slight changes in the characteristics of the whiskies produced.

Distilled wine is known as brandy and is further identified by the name of the fruit, if not derived from grapes.

Brandy is often added to wines to bring up the alcoholic content.

Distilled liquor is often diluted with purified alcohol, which may be derived from almost any source of sugar or starch. In Germany the potato is largely used for industrial alcohol production. In tropical countries molasses is generally the cheapest source of fermentable sugar. In the United States maize is often used in competition with molasses.

Other sources of beverage alcohol are found in coconut milk and in the sap of certain tropical palms. Fermented and distilled molasses, known as rum, was formerly a widely used spirituous liquor but its consumption has decreased in late years.

Condiments.—There are two classes of food stuffs which cannot be classed with any of the foregoing. They are condiments and the beverage substances. The condiments are of the greatest variety and come from all corners of the earth. Mineral substances, seeds, barks, roots, dried and powdered fruits and vegetables, and numerous others are included. Condiments are intended to appeal to our senses of taste and smell. It has often been shown that digestion is greatly influenced by the taste and odor of our foods. It therefore follows that condiments, and of course the natural flavor of foods, are of the greatest importance and should have the most careful consideration.

Our sense of taste is able to distinguish four sensations; these are bitter, sweet, salt and sour. The bitter taste is seldom appealed to by condiments. There are liquids called bitters used as a constituent of alcoholic

beverages but their use is by no means universal. Coffee and tea are to a certain extent bitter but there are also present volatile oils which appeal to the sense of taste.

Cane sugar might be classed as a condiment, but this use is of course overshadowed by its great importance as a food substance. Saccharin, a synthetic chemical substance derived from coal tar, is said to be five hundred times as sweet as sugar. It is frequently used as a sweetening agent for invalids who cannot tolerate sugar in large amount. It has no food value. There are many condimental combinations containing sugar which can be better discussed elsewhere.

There are a great many mineral substances having a salty taste but our bodies seem to crave but one. That is sodium chloride, or common salt. Salt is used almost universally. Its use is mentioned in some of the oldest records of man. Salt is an important constituent of our body fluids and apparently must be replaced and renewed at intervals. Practically all of our foods contain salt in small amounts. It is possible to get all our salt supply from our natural foods, as is proved by certain savage African tribes, who do not know salt as such.

Our "sour" taste is tempted by several acid substances. Among them are acetic acid (vinegar); citric acid (from lemons); tartaric acid and its salt—potassium acid tartrate, or cream of tartar; Lactic acid (made from sugars by the same bacteria that sour milk); carbonic acid, in soda water and some others of minor importance. The only mineral acid used to any great extent is phosphoric acid. This is used in several cooling beverages.

Acetic acid, the most important of the food acids, is made from sugar by way of alcohol. The sugar is first fermented to alcohol as in the production of fermented and distilled liquors. The fermented liquor containing alcohol is then acted upon by a peculiar micro-organism which has the property of converting alcohol very efficiently into acetic acid. Vinegars are distinguished from each other by the liquid or raw material from which they are made. Cider vinegar, wine vinegar and malt vinegar are all important table vinegars. Spirit vinegar made from distilled alcohol which has been diluted and acted upon by acetic acid bacteria, is very important commercially. Both acetic and lactic acids are also important as food preservatives.

Carbonic acid, or carbon dioxide gas, is extensively used for giving an acid tang to beverages. It also has the property of accentuating flavors. Carbon dioxide is a gas and must be dissolved in water in order to bring out its acid properties.

Another class of condimental substances does not appeal to the four taste sensations or to the sense of smell. These substances produce a burning sensation on the tongue and other mucous membrane. Ginger, black pepper and several species of red pepper fall into this class. There are several other plants which contain similar irritating principles but these are seldom used in foods. Ginger and all the varieties of peppers contain other flavoring ingredients which appeal to the sense of smell in addition to their burning principles.

We now come to a much more varied class of condimental substances which appeal exclusively to the sense

of smell. Of course all these substances may be sensed or "tasted" in the mouth, but the sensations are carried to the brain through the organs of smell. The principal members of this class are the spices—cloves, cinnamon, allspice, coriander, nutmeg, mace, etc.; the essential oils—oil of orange, oil of lemon, oil of almond, etc., the natural fruit flavors and the vanilla and tonka beans. These are assisted by synthetic substances and—as in the case of vanillin, the active principle of vanilla—synthetic reproduction of the substances themselves.

We are so constituted by nature that we constantly crave a variety of foods and food flavors. This is a very wise provision, as otherwise we would not get the variety of salts, protein constituents, vitamines, etc., that our bodies require. By the skilled use of flavors, we stimulate our appetites for a greater variety of foods and, at the same time, make appetizing, foods that may have lost their flavor in the manufacturing processes that many foods require for transporation and preservation. Everyone has noted, however, that we rapidly tire of highly flavored foods. We also note that our staple foods, such as cereals, meats, potatoes, etc. are very deficient in flavor, being in fact comparatively bland. For this reason we do not tire of them and are able to consume them daily for long periods of time. The freedom from flavor of these basic foods makes it easy to change the flavor when served by the use of suitable condiments.

Some flavoring oils, notably oil of cloves, have marked antiseptic powers. Others have the ability to repel insects.

Flavoring substances, practically all of which are

volatile oils, are very sensitive and are prone to rapid changes. They are lost by evaporation and undergo chemical changes, chief of which is oxidation. This applies to the flavoring oils in our natural foods even more than to those used as condiments. Many essential oils are articles of commerce for the very reason that they are stable enough to stand the extraction and refining processes without decomposing.

Beverage Substances.—Tea, coffee, cocoa and a few other beverage substances belong in a distinct class for the reason that they characteristically contain stimulating drugs and because, with the exception of cocoa, they are almost without food or energy value. Tea is the beverage of a very large percentage of the population of the earth. Its popularity is based primarily on the stimulating qualities of the drug caffeine. Practically everyone who does not drink tea, drinks coffee, and, upon analysis, we find that caffeine is at the bottom of the popularity of coffee also. Of course, both these drinks have flavors that are pleasing to the palates of the majority, but there is little doubt that other leaves and seeds could be found that would have an equally good flavor. It is no mere coincidence that tea and coffee have been selected as the favorite beverages of the world, if we except, perhaps, the alcoholic liquors.

Attempts have been made to substitute various roasted grains and dried fruits for coffee, but with little success from the quantity standpoint. One substitute, said to be a combination of roasted wheat bran and molasses, has achieved considerable success in this field in the United States.

Cocoa also contains a stimulating alkaloid, called

Theobromine. It is closely related to caffeine but does not possess as much stimulating power. Cocoa, however, is a real food, ranking very high in calorific or energy value. The flavor of cocoa soon palls, however, and therefore it has never gained the popularity that its other qualities deserve.

CHAPTER III

CAUSES OF FOOD SPOILAGE

Classification of Spoilage Causes—Animal Life—Insect Life—Micro-organisms—Bacteria—Yeasts—Molds—Effect of Micro-organisms on Cereals—Legumes—Nuts—"Vegetables"—Fruits—Edible Fungi—Flesh Foods—Milk—Eggs—"Refined" Foods—Baking Products—Confectionery—Non-alcoholic Beverages—Alcoholic Beverages.

The causes of food spoilage and deterioration are indeed numerous but all causes lead to the single result of making the food useless for the purposes for which it was preserved. The systematic study of these causes is therefore of the greatest importance in the work of disclosing the underlying principles upon which methods of food preservation should be based. The following classification includes the more important causes of loss, spoilage and deterioration of foods. It will be noted that many of them act upon the food substances in combination. It is obvious that many of the causes listed are sufficient in themselves to cause the destruction of the foods upon which they act.

Causes of Spoilage

I. Animal Life

1. Mammals
2. Birds

II. Insect Life

III. Micro-organisms

1. Molds
2. Yeasts
3. Bacteria

IV. Autolysis or Self-contained Enzymes

V. Chemical and Physical Decomposition

1. Oxidation
2. Light
3. Colloidal Reactions
4. Temperature Changes
5. Water Damage
6. Fire Damage
8. Humidity
9. Evaporation

VI. Contamination with Foreign Substances

1. Metallic
2. Chemical
3. Miscellaneous

Among the higher forms of animal life we need consider only the mammals and birds as means of destruction of preserved or stored foods. On consideration of these two classes, we find that bird-life as a means of destruction of stored foods plays a very minor role. It seems that man soon learned to protect his food hoard against thieving birds and mammals and very few of them have made any headway against the early methods of defense. Occasionally some isolated species breaks through and causes damage for awhile until brought under control by

man or natural enemies. Such a case is that of the English sparrow. Introduced into this country as a song bird, the sparrow soon developed into an insufferable pest. It soon ranged over the entire country preferring to feast upon stored grain rather than forage for itself. The sparrow is now losing some of its bad habits on account of the spread of natural enemies and changes in the methods of handling the food stuffs upon which it depended for existence.

Other birds do a great deal of damage to growing crops, but protection against them is so simple that there is little to fear from them even in the most primitive methods of storage.

Among mammals, the food preservationist has one arch-enemy—the rat. The several species of mice may be included in the same category. Through all the ages, the rat has been able to penetrate the most skillfully constructed storehouses. And almost the entire food supply of rats and mice is from the stores set aside by man for himself and his domesticated animals. It has been estimated that there are more than a quarter of a billion rats in the United States alone and that these rats eat a half billion dollars worth of food per year. Incidentally, the rat destroys other millions worth of property, spreads such diseases as bubonic plague and can be convicted of innumerable charges of arson without trial. The damage by mice is probably as great.

Of course a great deal of damage is done by other mammals than rats and mice, but most of them can be easily circumvented. Occasionally, as with birds, some mammal gains temporary superiority but it is soon

brought under control by man or by natural enemies. Most of the damage done to food stuffs by such mammals occurs during the productive stage rather than after storage or preservation. The habits of mammals are so easy to study and catalogue, that it is not at all strange that man soon learned to protect his food stuffs against most of them.

As soon as we begin to consider insect life in its relation to Food Preservation, we realize that we are contending against a much more formidable adversary than can be found among animal life. We find our foods followed by hordes of hungry insects from the fields to our very tables. Many of these insects have unbelievably strange habits of life. In others the complete life history is not known. It is only by the most careful study of their habits that we are able to work out methods of control.

Instances of insect damage to stored food can be produced endlessly. We have only to consider a few to realize the extent of the damage they are capable of doing.

Cereals are attacked by several forms of insect life. In fact insects, particularly the weevil, are probably the principal agents of destruction of stored grain all over the world. In grain elevators, flour mills and bakeries insects have to be fought with the expenditure of a great deal of time, money and trouble. The amount of grain actually consumed by insects is little compared with the amount contaminated by dust, excrement and other debris of their life processes.

Legumes and nuts are also subject to insect damage, the former by weevil and the latter largely by the Indian

meal moth. Insect damage in nuts is usually followed by rancidity, due to the exposure of the oil in the nuts to air.

Vegetables in the fresh state are usually stored at a temperature low enough to prevent the development of insect life. Canned vegetables are of course immune. It is only dehydrated vegetables that are particularly subject to insect contamination, but here the damage is severe.

Fresh fruits are subject to damage by the larva of an insect that deposits its eggs in the "green" fruit. Later these eggs hatch into larva which live in and feed on the fruit. Dried fruits are subject to the same insect pests as dried vegetables.

A peculiar instance of insect infestation is that of the tobacco or cigarette beetle. This beetle spends its entire life cycle in tobacco, feeding on it exclusively. This in spite of the fact that tobacco is a deadly poison to most insects and is used very extensively as an insecticide.

Flesh foods are as much subject to insect pests as vegetable foods. Fresh meats are used by several varieties of flies as a breeding place, although this condition is seldom allowed to take place. Salt meats and smoked meats are also infested by larva and worms, particularly when the salt or smoke has not been well applied. Some trouble is also caused in flesh foods by insect parasites which grow in the flesh of the animal during life. The most commonly mentioned of these parasites are small flesh worms called trichina, which cause a disease in swine and which can be transferred to persons eating infected pork. Thorough cooking of course kills the trichina.

Eggs and dairy products escape serious damage from insect pests largely because of the way they are handled. In its natural state, milk is subject to the attack of so many micro-organisms that insects do not have a chance. Eggs are naturally protected against insects by their shells. After an egg is broken, it is subject to the action of the same micro-organisms as milk.

In addition to attacking the natural foods which men gather and store, insects have adapted themselves to live upon manufactured foods also. Breakfast food cereals are attacked by the same weevils that infest grains. Crackers and cakes are invaded also. Candy and other confectionery becomes infested by moths, the eggs usually being deposited in the factory rather than in the store. Pure sugars, starches and oils are rarely attacked by insects, probably because none of them will support life alone. In combination with other food elements—even in small amounts—they are all eaten avidly.

Even such highly flavored products as pepper, paprika and cocoa are subject to the invasion of worms and larva of various kinds. In general it may be said that any natural food substance is subject to some form of insect attack. A few highly refined and purified foods are immune. Insect infestation is seldom noted in fresh vegetables, for instance, because these foods are subject to much more rapid agents of destruction, such as bacteria, yeasts and molds.

Bacteria, Yeasts and Molds

When we take up the subjects of bacteria, yeasts and molds, we enter a world that must be studied through a

microscope. And as we study this miniature world and realize the enormous capacity for destruction of its microscopic denizens, we are moved to wonder that any food can be preserved against their ravages.

At the mention of the word "bacteria," we are likely to think first of disease germs. The role of micro-organisms in the complicated natural cycles of growth and decomposition receives very little public attention. We cannot hope to comprehend the numbers of these bacteria that are constantly performing their natural functions in soil and water. The statement that the bacteria present in a handful of soil number, literally, billions, will give a faint idea. Compared with the enormous numbers of harmless and even beneficial bacteria, disease germs are probably rarer among bacteria than murderers among humans.

Bacteriology—the science of the study of micro-organisms—has taught us the relationship between spoilage and the growth of micro-organisms. Prior to the discovery of bacteriology certain methods of preventing bacterial spoilage has been developed, largely by accidental observation. These include drying, salting and smoking. These methods are based on the general principle of making the food product unfit as food for micro-organisms. In the case of drying, water—an absolutely essential element to all life—is removed, and without water all micro-organisms either die or remain inactive. In salting and smoking processes, the water in the food is made poisonous to bacterial life by the salt and the chemical compounds in the smoke without being made injurious to man.

It is only within the last century that we have learned to preserve foods by the exclusion of bacteria and other micro-organisms. This discovery marks the real beginning of the preservation of foods in hermetically sealed containers—the basis of our canned food industry.

Micro-organisms in general have no favorite food. It may be accepted as generally true that any food product which is exposed to the air under favorable conditions of moisture and temperature will be spoiled by some form of micro-organism. This means that everyone interested in food either as a producer or consumer is concerned with micro-organisms either consciously or unconsciously. Since we must associate with micro-organisms whether we wish to or not, some information about them will be of use in making this association as pleasant as possible.

For our own purposes, micro-organisms may be classified under the three headings—

Bacteria
Yeasts
Molds

The bacteriologist may not be satisfied with this classification but it divides micro-organisms into three sharp classes from the viewpoint of the food technologist.

Bacteria are the simplest and smallest forms of life. The individual bacterium reproduces itself by dividing into two bacteria. These in turn develop and divide in the same manner. This growth and division takes place in a very short time, in some cases requiring only thirty minutes for the complete cycle. At this rate it requires

only a few hours for some forms of bacteria to make food entirely unfit for food purposes.

Bacteria are commonly classified as

Bacilli
Cocci
Spirilli

This classification refers to the form of the bacteria; bacilli are cylindrical or rod-shaped, cocci are spherical or nearly so, and spirilli are curved in various shapes. Bacilli are the commonest forms, cocci fairly common and spirilli relatively rare. All forms of bacteria are very small, being visible to the naked eye only when present in tens of thousands. A colony of bacteria numbering hundreds of thousands appears to the eye as a tiny spot.

Bacilli are further classified as spore-forming and non-spore-forming. Non-spore-forming bacteria are confined to the previously described division method of reproduction. Spore-forming bacteria possess the ability to develop a comparatively thick-walled cell or wall in their interior. This spore when transferred to a favorable locality has the power of developing a normal bacillus which in turn can reproduce either by division or by spore formation.

All bacteria are destroyed by moderate heating, less than the temperature of boiling water usually being sufficient. Bacterial spores, however, are very resistant to heat, many of them requiring several hours boiling for destruction. Luckily most spore forming bacteria grow only in foods that are relatively free of acid and

for this reason we are able to keep our fine fruits with a short period of heating.

Bacteria are also differentiated by the terms "aerobic" and "anaerobic," which simply means that some require air while others are able to grow in the entire absence of air. Some bacteria are able to grow both in air and when air is excluded and are known as "facultative anaerobes."

Bacteria are constantly at work carrying on the building and demolishing activities of nature. In countless billions they are fertilizing the soil, decomposing wastes, purifying water and innumerable other activities. It is to be taken for granted, therefore, that bacteria are always to be contended with in our food preservation problems.

We are all familiar with the phenomenon of yeast "working" or fermentation in sugar syrups, fruit juices, etc. This is usually the work of minute plant organisms called yeasts. Yeasts are almost as simple in their habits of growth as bacteria. They are one-celled organisms and multiply by a sort of budding action, the young cell coming from the side of the mature cell and splitting off as it reaches maturity. Yeasts also form spores or seed which are capable of developing a new yeast cell from which an entire colony may grow.

Yeasts are quite sensitive to heat, being killed by exposure to 150° Fahrenheit for a few minutes. For this reason they are comparatively easy to control. On account of the fact that yeasts are almost aways present in the air and are continually dropping into our foods, they frequently cause trouble where vigilance is relaxed or where their habits of growth are not understood.

One species of yeast, saccharomyces cerevisae, has

been put into the service of mankind in bread making and the fermentation of alcohol. This yeast has the ability to convert sugar into alcohol and carbon dioxide very efficiently. In bread making the carbon dioxide is desired for leavening. Yeast and other alcohol producing organisms will probably take on added importance as petroleum becomes exhausted and a cheap motor fuel is demanded.

Molds as agents of spoilage are very familiar. Almost everyone has seen the common green or blue mold growing on top of a jar of jam or on the surface of over-ripe fruits. Molds that have reached their full development are readily visible to the naked eye but in their earlier stages of growth they are capable of doing great damage without being visible. Spoilage caused by molds which start to develop and then die on account of drying or other causes are often very difficult to trace. In oily products particularly, a slight development of mold growth is capable of producing complete destruction for food purposes by initiating rancidity.

The first stage of mold growth is a thread-like form called mycelium. When a mold has developed profusely, the interlaced mycelia have the appearance of fine cotton wool. The mycelium of a mold serves the combined purposes of the roots and leaves of an ordinary plant. When the mycelium has reached a certain stage of development, the mold forms a sort of seed pod, usually in the form of a vertical thread or stalk surmounted by the spore-head or conidium. The mushroom is a familiar example although of course greatly enlarged. The spore-heads of the common molds are visible as dots, usually of

some dark color such as brown, black or green. These sporeheads give the molds their characteristic color. The individual mold spores are visible only through the microscope.

In general, yeasts, molds and bacteria attack all classes of foods with almost equal avidity, provided conditions of moisture and temperature are correct. When dealing with specific organisms, this is not true, as individual species have very marked preferences. There are so many varieties of these micro-organisms, however, and they are so widely and thickly distributed, that we may usually be sure that there is an organism present in every case, capable of spoiling food if the right conditions for growth exist.

When we consider the separate classes of foods with relation to their spoilage by micro-organisms, we find that cereals and legumes are immune from such spoilage as long as they remain dry. Water damage or even exposure to air of a very high relative humidity will usually result in damage by mold. Damage of this kind often takes place when grain is newly harvested or when it is stored in a poorly ventilated place before being allowed to dry thoroughly.

Cereals and legumes which are prepared for use as food with large amounts of water are subject to damage by all forms of spoilage micro-organisms. Canned corn, when insufficiently sterilized by heat, or when imperfectly sealed, is spoiled by bacteria—usually of the spore-forming variety. Bacteria which spoil canned goods usually form gas but canned corn is particularly susceptible to a form of spoilage called "flat sour," caused by a

non-gas forming bacillus which produces acid from the sugar of the corn. Corn is also subject to spoilage by a spore-forming bacillus which grows at a very high temperature, called thermophilic or heat-loving bacteria. Thermophilic bacteria get a foothold when the corn is not thoroughly cooled after sterilization. By storing the cans in large piles, the internal heat is preserved for a time sufficient to insure the development of these bacteria. Canned peas are subject to the same forms of spoilage by micro-organisms as canned corn, both products containing ample water for bacterial development and both falling into the same general class with regard to acidity and chemical composition. This also applies to canned mixtures of corn and beans.

Cereal products such as bread and cake and other baking and confectionery products are all subject to mold infection and—rarely—to infection by bacteria and "wild" yeasts. Bread containing excessive moisture and which has been made under unsanitary conditions, frequently becomes sour and shiny in the center of the loaf. This is due to the growth of a spore-forming bacillus which is not killed during baking.

Nuts are subject to the attacks of molds unless thoroughly dry. Some nuts, such as coconuts and green brazil nuts, the meat of which is very wet, will support the growth of bacteria, yeasts and molds and are comparatively difficult to preserve without drying.

The damage done by molds to the nut crop is enormous. Mold spores get in contact with the nut meats immediately after shelling and often completely destroy them, before they can be dried out. Some molds do not

materially change the flavor of nut meats until they reach full development. Others cause rapid breaking down of the oil in the nut and in conjunction with the oxygen of the air cause the disagreeable change known as rancidity. Rancidity in nuts may first be evident as a slight disagreeable taste and odor. Later this taste and odor becomes very rank and anyone eating a really rancid nut is likely to become nauseated. Often the decomposition of unshelled nuts infested by molds goes so far that only a brown powder is left in the shell as evidence that it had ever contained a nut meat.

Our "vegetable" class of foods is particularly liable to spoilage by micro-organisms. As a class, these foods contain large quantities of water and are low in acid content. These conditions make them susceptible to the invasion of almost every kind of bacteria, yeasts and molds. Many vegetables, such as the potato, turnip, radish, etc., are provided by nature with a thick rind which resists the invasion of micro-organisms to a certain degree. Others such as lettuce and cabbage are easily penetrated and spoiled. Once the watery interior of a vegetable is reached, it is only a matter of hours when the vegetable will be infected and spoilage begin. The character of the spoilage will depend on the kind of micro-organism that first gets a foothold. The microscope will often reveal yeasts, molds and several kinds of bacteria growing together. It is on account of these microscopic enemies that most fresh vegetables have to be shipped under refrigeration. Even such resistant vegetables as potatoes must not be exposed to too great extremes of temperature and humidity.

The susceptibility of vegetables to spoilage by micro-organisms has made them particularly difficult to preserve. It was not until the invention of canning in hermetically sealed containers by Appert that a satisfactory preserved product could be put up and kept from year to year.

Bacteria usually make themselves evident in canned vegetables by the evolution of gas, causing the ends of the can to bulge. The canned product also, in most cases, develops an objectionable odor and taste. Most of the spoilage of canned goods is due to the action of anaerobic spore-forming bacteria. Yeast, molds and other bacteria are eliminated by the severe sterilization required by all canned vegetables. Of course when the container is imperfectly sealed, almost any micro-organism is likely to gain entrance to the can. Some may fail to develop on account of unfavorable conditions. Often bacteria get into a can and start to develop, giving off gases as they grow. The escape of the gas through the leak causes particles of food to get into the hole and close it. The further evolution of gas causes the can to swell in the same manner as a can spoiled by an anaerobic spore-forming bacillus.

All fruits are subject to the action of micro-organisms, chiefly of the mold and yeast class. Bacteria are prevented from growing in most fruits on account of the presence of fruit acids. Unripe fruits are usually protected from micro-organisms by a rind or peel. When the fruit ripens, the yeast or mold gets a start through the bite of an insect or a bruise or abrasion on the surface. Tropical fruits, such as bananas, grape fruit, pine-

apples, etc., are protected from insect and subsequent spoilage by micro-organisms, by tough, thick skins. Many of these rinds or skins are saturated with antiseptic substances or odoriferous substances which are repellent to insects. Citrus fruits are typical examples.

Dried fruits are likely to become overgrown with molds and yeasts if moisture conditions are not carefully controlled. Many dried fruits are rich in invert sugar or "fruit" sugar which absorbs moisture from the air when the relative humidity is high. This is of course favorable for mold growth.

When canned fruit is spoiled by micro-organisms, yeasts are usually to be found at the bottom of the trouble. Yeast spoilage of canned fruit may be due to defective sealing or to insufficient heating. Yeasts are always present on the surface of fruit and are certain to develop if the fruit is not heated enough to kill them. The killing temperature is in the neighborhood of 150°F. but varies for different kinds of yeasts. Yeasts are so easy to kill by ordinary canning methods that commercial canneries are seldom troubled with them. Home canned fruits are often spoiled by yeasts on account of unsanitary methods of handling and packing in containers.

Edible fungi—principally mushrooms and commercial yeast—are as susceptible to the attacks of micro-organisms as the most sensitive of vegetables. Mushrooms, fresh and canned, are liable to very disagreeable bacterial putrefactions. Prepared yeasts are very prone to become infected with foreign organisms. In fact no commercial yeast is entirely free of them. Heavily infected yeasts do not yield a normal fermentation when used in bread

making or for brewing, wine making and other fermentation industries. When the infection is slight, the invading organism is soon overgrown by the yeast to such an extent that the fermentation does not exhibit any abnormal characteristics.

Flesh foods of all kinds are favorable mediums for the growth of bacteria. This is particularly true of fresh flesh. Only by careful temperature control and sanitary handling can meats of any kind be preserved in a fresh state for more than a few hours.

Yeasts and molds seldom affect fresh meats. If the conditions for mold and yeast growth are at all favorable the chances are all in favor of the meat being overgrown with bacteria before the yeast or molds get a foothold.

Salt-cured meats may become infested with molds, especially if not allowed to become thoroughly surface dry. Mold growth on bacon and cured beef has been controlled by packing in vacuum in glass jars. Bacterial growth, except in rare instances, is prevented by saturation of the food product with a strong salt solution. An exception to this is salt fish, which is attacked on the surface by a bacillus even when the fish is covered with moist salt crystals.

Smoked meats and fish are quite immune from attack by micro-organisms for short periods when temperature conditions are favorable. Their resistance depends on the duration and thoroughness of the smoking process. Flesh smoked for a few hours is not a great deal more resistant than fresh meat. Thoroughly smoked meats or fish which are dried considerably will resist micro-organisms almost indefinitely, if perfectly stored.

Canned meats and fish are seldom affected by organisms other than bacteria. Yeasts and molds are killed by the long sterilization periods used. Most of the trouble is caused by resistant spore-forming bacteria. In modern plants, efficiently conducted, even this spoilage has been reduced to a minimum.

The bacteriology of milk and its products has been the subject of many books. From our standpoint, however, it is very simple indeed. Milk is an almost neutral product containing a high percentage of water and all the necessary bacterial foods. It is a foregone conclusion, therefore, that it will serve as a breeding place for countless micro-organisms under favorable temperature conditions.

The handling of the milk supply for our cities is an enormous and complicated industry and at almost every point we run into the practical application of Industrial Bacteriology. The marketing of milk is a constant struggle against contaminating micro-organisms from the time it leaves the cow until it is safe in the baby's nursing bottle. The dairy farmer must keep his cows and stables clean as well as his milking machines, utensils and the persons of himself and his employes. The milk dealer must use the same precautions in his tanks, vats and bottle filling machines. After this the milk must be kept cool and used quickly. Yet we are likely to find a million bacteria in a drop of milk that comes to our table.

The commonest change made by bacteria in milk is the formation of lactic acid or "souring." The bacteria causing this change are called lactic acid bacteria and

they produce a characteristic flavor in milk in addition to producing acid. Lactic acid bacteria are as a class non-spore forming and for this reason are easily killed by a mild heating, such as is used in "pasteurization." Pasteurization is intended primarily to kill disease germs which also are easy to kill by heat. If pasteurized milk is allowed to stand for several hours at a normal temperature, it does not become sour but turns putrid by the action of the spore-forming bacteria which have survived the pasteurization. Lactic acid bacteria are cultivated and used in creameries to develop the typical butter flavor in pasteurized cream.

Yeasts and molds find a very favorable medium for growth in fresh milk. Usually they are soon overgrown by the more rapidly growing lactic acid bacteria. Under special conditions, however, mold and yeast spoilage often occur. In some countries, particularly in the Balkans, fermented milk has been a favorite beverage for centuries. This beverage, known under various names such as yoghurt, koumiss, etc., is prepared by inoculating milk with a crudely prepared yeast culture. So much of the yeast is added to the milk that the lactic acid bacteria normally present do not have a chance to develop before the yeasts have completely taken possession. Within a few hours the yeasts convert part of the milk sugar into alcohol which acts as an antiseptic and stops further growth of most bacteria.

Molds on milk and cream are almost always seen after the bacterial action has fully developed. Then certain molds which are able to grow in the presence of lactic acid start to develop on the surface of the soured milk

or cream. This is most often seen on cream accumulated by dairy farmers for shipment to city creameries.

Eggs in the shell are well protected from micro-organisms not only by the hard shell but by a hard film of dried mucus which covers the egg. Under normal conditions a clean egg will gradually dry completely in the shell without becoming decomposed. When brought in contact with dirty water or moist soil, the mucus membrane is dissolved, and bacteria, yeast or molds gain entrance through the porous shell. Spoilage then becomes a matter of hours.

All classes of micro-organisms grow in eggs when temperature and moisture conditions are suitable. Yeasts and the acid-forming bacteria, however, do not develop so well on account of the lack of sugar in eggs. Putrefying bacteria find conditions in eggs exactly to their liking and a rotten egg has become the standard of comparison for the worst of bad odors. Molds often grow on the surface of dirty eggs and sometimes the tiny mold threads find their way through the pores of the shell. This of course causes a very disagreeable form of spoilage.

Within the last few years the expansion of the baking and confectionery industries has created a large demand for frozen and dried eggs. Both these products present serious problems in food preservation. As soon as the egg shell is broken, the egg instantly becomes fair game for any micro-organism that falls into it. In the case of frozen eggs, the packer must get the product chilled and into cans in the shortest possible time after breaking. The problem is complicated by the fact that a single

rotten egg broken by mistake may contaminate the entire contents of a thirty pound can. The dryer of course has the same problems and in addition must look out for overheating, metallic contamination, etc. After the eggs have been safely mixed and frozen (or dried), they are still endangered by micro-organisms. Frozen eggs, being usually inoculated with tens of thousands of bacteria per gram, are likely to spoil if their temperature rises even a few degrees. The breaking down of a refrigerating plant may cause the spoilage of hundreds of thousands of dollars worth of first class food. Dried eggs are comparatively free from bacterial spoilage but may develop mold growth if allowed to take up moisture from the air. Of course dried eggs made from eggs that are damaged by micro-organisms are just as bad as they were originally. The drying process cannot improve the quality of bad eggs, although many manufacturers have apparently believed so.

Spoilage by micro-organisms in "manufactured" and refined foods is governed by their chemical composition, water content and their "reaction" (acid, alkaline or neutral). For instance purified sugars and starches are never affected by micro-organisms as long as they remain dry. Even when moist they are open to attack by only a few specialized fungus forms, for the reason that they are practically pure carbohydrates and do not furnish the "balanced ration" needed by most micro-organisms. Oils and fats are practically immune from damage by micro-organisms when purified and freed from water. When in the original animal or vegetable tissue or when in contact with water or with moist organic matter, fats

and oils break down and become acid and—finally—rancid under the influence of the growth of molds or bacteria.

Bakery and confectionery products are troubled with yeasts and molds but comparatively little with bacteria, on account of the large amount of sugars they contain and their comparative freedom from water. Other causes of spoilage, which will be discussed later, are a great deal more destructive to this class of food.

The non-alcoholic sweet beverages are frequently spoiled by yeast development. They are seldom attacked by molds and rarely by bacteria. Their composition is almost ideally suited to the growth of both yeasts and molds but the molds are held back by the exclusion of air from the beverage containers.

Distilled liquors are entirely free from infection by micro-organisms on account of their high alcoholic content. A liquid containing as much as twenty percent of alcohol may be said to be perfectly preserved against the development of yeasts, molds and bacteria. The fermented liquors, such as beer, ale, wines, etc., may become infected by certain specialized forms or microscopic life which are able to exist in low concentrations of alcohol. One of the commonest of these forms is mycoderma aceti or "mother of vinegar," a surface growing organism that has the ability to convert alcohol into acetic acid, the acid of vinegar. Other organisms are likely to develop to a limited degree causing cloudiness in the liquids. In most fermented liquors, the fermentation stops at a point when all the sugars have been consumed, or when the percentage of alcohol has reached the point where the

organism can no longer grow in the liquid. This creates an equilibrium which is very easily disturbed. A change of temperature, filtration or even moving the container is likely to cause the fermentation to resume—sometimes with disastrous results. In making champagne, the secondary fermentation is made use of, a quantity of sugar being added to the wine after the first fermentation for the purpose of inducing the second. The bottle being closed, the second fermentation produces gas under pressure, causing the effervescence of sparkling wines.

Considering spoilage by micro-organisms as a whole, the main factors influencing their growth in foods are

1. Water Content
2. Reaction (Acid, Alkaline or Neutral)
3. Chemical Composition
4. Temperature

Water is an essential to all known forms of life. A reduction of the amount of water in a food product immediately restricts the number and variety of micro-organisms able to exist upon it. The degree of acidity or alkalinity of a food product also has a great deal to do with its resistance to the attacks of micro-organisms. Yeasts and molds grow readily on strongly acid fruits. The more heat-resistant bacteria can tolerate very little acid but grow profusely in neutral vegetables like asparagus, spinach, etc.

Minor differences in chemical composition of foods are of very little importance in comparison with their water content and acidity. It is only when an ingredient is

present in predominant quantity that this influence merits much consideration. For instance it makes very little difference as far as spoilage is concerned whether milk contains three or five percent of milk sugar, but the difference between ten percent of sugar and sixty percent makes the difference in keeping qualities between sweetened and unsweetened condensed milk.

Temperature of storage is of course a very important factor in the growth of spoilage organisms. Micro-organisms will be found that grow all the way from the temperature of an ice-box up to 130 Fahrenheit. The temperature in which individual species can grow, however, is small and the growth of micro-organisms in most foods can be controlled by proper refrigeration.

CHAPTER IV

CAUSES OF FOOD SPOILAGE (CONTINUED)—ENZYMIC CHANGES

Action of Enzymes on Foods—Effect of Enzyme Action on Cereals, Legumes and Nuts—Fruits and Vegetables—Fungi—Flesh Foods—Milk—Eggs—"Refined" and "Manufactured" Foods—Beverages.

Before going into a discussion of the influences of enzymic action on the problems of food preservation, a brief description of enzymes is in order. When asked, "What are enzymes," we are at as much of a loss for a reply as when we are asked, "What is electricity." We can only study them and know them at present by what they do. The results of enzyme action in every day life are quite apparent to any observer. Enzymes function so quietly and efficiently, however, that their work is often overlooked or attributed to some other agency. The simplest way to impress the importance of enzymes on our minds, is to realize that every structural change in a living thing is carried on by enzymes and that without enzymes, life as we know it would not exist.

As an illustration of enzymic action, we might take our own digestive processes. Our food while being chewed is mixed with saliva, a fluid which contains several enzymes of minor importance to digestion. When swallowed, the food goes into the stomach where it becomes mixed with the gastric juices, which also contain

several enzymes in an acid medium. The principal enzyme in the gastric juice is pepsin, the main function of which is to break down the complicated protein substances into soluble constituents, ready to be built into our own flesh. Our food then travels to the intestine, where it receives the alkaline secretions of the pancreas, which contain still another series of enzymes able to assist in the digestion of the carbohydrate, fat and protein constituents of our diet. By the time our food has run the gauntlet of our digestive enzymes, everything of value has been extracted and made soluble and available for transportation to all parts of our bodies by the blood stream.

In the simplest forms of life the digestive processes are very similar. Bacteria for instance live in or upon their food and excrete their digestive ferments. When their food substances are made soluble, they are able to take them within their cell walls and use them as a source of energy and material for growth and development.

These enzyme changes are, of course, all functions of living organisms. When a living organism—plant or animal—is killed, its enzymes are not necessarily destroyed. Seeds, eggs and other dormant forms of life also contain active enzymes. It is with these enzymes that we are principally concerned in food preservation.

Our chemical knowledge of enzymes is very limited. Chemists have never been able to free enzymes from nitrogen-containing substances and have concluded therefore that they resemble proteins in composition. It is known that enzymes are intensely active, pepsin preparations having been made which are able to digest and

make soluble several thousand times their weight of coagulated white of egg.

Enzymes have been classified in detail in accordance with the functions they perform. There are protein decomposing enzymes called proteinases, starch-digesting enzymes or diastases and fat-splitting enzymes or lipases. There are also enzymes of importance which coagulate proteins and assist in oxidizing reactions and others which assist in building up organic compounds in living tissues. In the spoilage of cereal grains, spoilage by enzymic action must always be considered, particularly in relation to the water content of the grain. Each grain is a seed, requiring only favorable moisture and temperature conditions to start sprouting. Sprouting changes are almost entirely enzymic in character. The natural enzymes of the seed decompose the starch into sugars for the nourishment of the plant embryo and undoubtedly carry on other reactions. Barley, which has been sprouted and dried to arrest further enzymic action, is an important article of commerce. Its value depends on its ability to convert, by its dominant enzyme—diastase, starches from other grain into sugars. Barley thus treated is known as malt and is extensively used in the brewing and distilling industries and in the preparation of malt extract, malt syrup, malted milk, etc.

Legumes and nuts also contain enzymes intended to promote the growth of the young plant and are liable to spoilage from the same enzymic causes as the cereal grains. Nuts contain a high percentage of oil instead of starch as a course of energy for the plant embryo.

Therefore the principal enzymes of nuts are characterized by their fat-splitting ability rather than their ability to decompose starch.

Fruits and vegetables in general all contain active enzymes while in the raw state. Many changes carried on by these enzymes are very little understood. Others are very apparent to the most unskilled observer. Everyone has noticed that a freshly-cut apple soon becomes brown on exposure to the air. This is an enzyme change carried on by an oxidase or oxidizing enzyme. Almost all fruits contain oxidases in greater or less amounts. Their presence is a very serious obstacle to many drying and dehydrating processes. Sulphur dioxide is often used to counteract the effect of browning due to oxidases.

Many flavor changes that go on in fresh fruits and vegetables are undoubtedly caused by enzyme action. Some of these changes are so rapid that they defy all methods of food preservation. Everyone has noted the difference in flavor between freshly-gathered vegetables and those eaten several days after gathering. The change in the flavor of fresh fruits a few hours after gathering is also marked, especially if the fruit has been pared or cut so as to expose the interior to the air. All these changes require very serious consideration in the handling and marketing of fresh fruits and vegetables. They are also important to all canners and preservers, who must exercise the greatest care to provide against enzyme changes before their product goes into containers.

Edible fungi such as mushrooms and yeast are rich in enzymes. Mushrooms are particularly rich in oxidases which cause them to turn black very quickly on exposure

to air, particularly if the cells are ruptured by crushing or cutting. Yeast contains an enzyme, zymase, which has the peculiar ability of converting sugar into alcohol. Fungi are so quickly spoiled by bacteria that the action of enzymes is often overlooked. There can be little doubt, however, that much of the difficulty in keeping fungi is due to the action of enzymes.

In flesh foods of all kinds enzymes of varying amounts are found. When an animal is killed, the enzymes in the cells and body fluids are functioning and it is to be expected that these enzymes will retain at least part of their activity. In modern packing plants, the larger animals are killed and handled with such quickness that the effect of self-contained enzymes is reduced to a minimum. The flesh of fowls and fish is often softened by the action of enzymes. This action is hastened by high temperature although it takes place to a degree when the flesh is comparatively cool. Sardines and other small fish when taken from warm water often get so soft that they cannot be handled in the factory. A great deal of this softening effect is due to enzymes which diffuse into the flesh from the digestive tract. The digestive fluids of fish are very rich in enzymes and a very few hours exposure in a warm place often softens the flesh to such a degree that it almost falls apart.

The action of enzymes on flesh is taken advantage of by the British in their custom of "hanging" game and other flesh foods. In this process the flesh, which is exposed to the air for days or even weeks at an ordinary cool temperature, becomes tender and undergoes some desirable flavor changes. The tendering of the flesh is

probably due to proteolytic or protein splitting enzymes which would have a tendency to soften the muscle fibres by decomposing some of their contituent protein substances.

Milk and its products are very sensitive to the action of enzymes although it is very hard to attribute any direct action to the natural self-contained enzymes of milk on account of the almost universal presence of bacteria. However, the changes if they exist cannot be of very great importance.

Eggs of course contain enzymes and means for producing enzymes, for without enzymes the egg could not produce life. Very little is known regarding the relation of these enzymes to changes in eggs in storage, although there is little doubt but that they have some effect. As in milk, we have a great deal of difficulty separating the enzyme changes from changes caused by bacteria and other causes.

In manufactured foods we need give but little consideration to enzymes. In most manufacturing processes the food is either subjected to heat or chemical refining, and this can usually be depended upon to destroy all enzyme activity. Sugars are put through boiling and crystallizing processes. Oils and fats are heated, bleached and deodorized with chemicals. Bakery and confectionery products are all subject to heat which is usually ample to inactivate all enzymes.

Soft drinks of the "sugar base" class are usually combinations of refined substances relatively free of enzymes. When fresh fruit juices are used they are submitted to heat which is sufficient to destroy most of the enzymes.

Fermented liquors are a product of yeast fermentation which is of course carried on by enzymes. The end product undoubtedly contains active enzymes and these may be one of the causes of the formation of precipitates and certain flavor and color changes that occur in these beverages. An enzyme—pepsin—has actually been added to beer for the purpose of digesting certain protein substances which separate upon cooling, causing cloudiness. By the addition of pepsin, a "chill-proof" beer is produced.

Distilled liquors being produced entirely by distillation and being therefore volatile, cannot contain even a trace of an enzyme.

In dealing with enzymes in food products in general, it must be remembered that they are able to make very marked changes in a product in a very short time. They are also likely to remain dormant for months and then start acting when conditions of moisture and of temperature are favorable. Being part and parcel of the food itself they are always in a position to act. In this they differ from micro-organisms, insects, etc., which must first gain access to all parts of the food and usually go through time consuming reproducing processes before their action becomes evident.

For the most part enzymes are easily destroyed by heating to temperatures of about 150°F, in presence of water. They are also rendered dormant by dehydration. For these reasons they are comparatively easy to control in most processes of food preservation.

CHAPTER V

CAUSES OF FOOD SPOILAGE (CONTINUED)—PHYSICAL AND CHEMICAL DECOMPOSITION

Classification of Physical and Chemical Spoilages—Oxidation—Light—Colloidal Changes—Temperature Changes—Changes Caused by Low Temperatures—Changes Caused by High Temperatures—Spoilage by Extraneous Water—Fire Damage—Damage Caused by Humidity—Damage by Evaporation—Miscellaneous Physical and Chemical Spoilages.

Before the discovery of micro-organisms and the action of enzymes, food and its spoilage problems, when thought of at all, were considered in physical and chemical terms. We realize now that most changes that go on in our stored foods are started by bio-chemical means. Development of knowledge of the influence of micro-organisms and enzymes on food decomposition came at such a rapid rate that the more inconspicuous chemical and physical changes have been for the most part overlooked. In almost all classes of foods, however, these changes are at work and the student of food preservation methods cannot afford to overlook any of them.

For convenience, we may divide the ordinary physical and chemical causes of food spoilage into classes as follows:—

1. Slow Oxidation
2. Light
3. Colloidal Reactions
4. Temperature Changes
5. Water
6. Fire
7. Evaporation

These classes undoubtedly do not cover all instances of spoilage due to physical and chemical changes but do include most of the deleterious changes that have been studied at all thoroughly.

Oxidation

Oxidation is probably the most important of the chemical changes affecting foods. Oxygen is particularly damaging to foods containing large percentages of fats and oils. It also has a very bad effect on foods containing delicate essential oils.

Cereals as a class are almost exempt from oxidation changes. Their principle constituents, carbohydrates and proteins, are not noticeably affected as long as they are dry. Legumes, as a class, are also exempt from oxidation spoilage, with the exception of those containing high percentages of oil. Nuts, as a class, are particularly subject to oxidation because of their high oil content. Very few nuts will keep for many months in their original shell. When the shell is removed, the oil is better exposed to oxygen and spoilage takes place at a still greater rate. Oxygen spoilage of nuts is often helped

by molds which cause a partial decomposition of the oil. This is followed by oxidation which produces a particularly disagreeable form of rancidity.

Vegetables and fruits in the fresh state are, in general, affected with respect to flavor and color by oxygen, usually through the agency of self-contained oxidizing enzymes. Flavor and color changes particularly in these two classes of foods are next to impossible to measure accurately and therefore very little is known about them. The crudest obesrvation, however, establishes the fact that the changes are very different in kind and degree in different fruits and vegetables. Observation is also greatly handicapped by the fact that oxidation changes are often complicated by changes due to microorganisms and enzymic activity and probably other strictly chemical changes. It is not remarkable, therefore, that we should still have a very great deal to learn in this field.

Mushrooms, among the edible fungi, are particularly liable to oxygen color and flavor changes. Freshly picked mushrooms will turn black within a few hours at ordinary temperature where the flesh is cut or broken. This change is undoubtedly accelerated by oxidases but continues at a slower rate when the enzymes are destroyed by heat or prevented from acting by chemicals.

Very little oxidation damage has been noted on fresh flesh food of any kind. Oxygen is very probably one of the causes of flavor changes in cold storage meats but this has not been well confirmed by scientific study. Salt-cured meats and fish are affected by oxygen to a much greater extent. The fatty matter in these foods

becomes rank and rancid with age, often becoming unfit for consumption.

Fresh milk is not noticeably affected by the oxygen of the air. Other changes usually make themselves only too evident before oxygen can get in its work. It has been asserted and fairly well proved, however, that oxygen has a pronounced destructive effect on the vitamines of milk. In milk powder or dried milk the action of oxygen is seen at its worst. This product first begins to acquire a "tallowy" odor after about two or three months exposure to the air under ordinary conditions. Later the oxidation of the fat proceeds until it becomes disgustingly rancid.

Rancidity of butter is a spoilage change with which oxidation has a great deal to do. This change is also helped along by natural enzymes contained in the butter. Oxygen plays a great part in the ripening of cheese. It is also instrumental in disagreeably changing the flavor of some cheeses under certain conditions.

Eggs consumed in a fresh state are not sensibly affected by oxidation. The flavor of cold storage eggs is undoubtedly changed somewhat by oxygen although the extent of the damage is very difficult to determine. In frozen eggs, the action of oxygen on the yellow coloring matter of the yolk is very apparent. Frozen egg yolks in cans are often found to be bleached two or three inches from the top of the surface after a year in storage.

Manufactured foods are usually subject to oxidation in proportion to the amount of fatty matter they contain Sugars and starches are immune, for they contain no fats or delicate flavoring oils. Edible oils and fats are

of course easily oxidized and made rancid. Millions of dollars are spent annually in removing the products of oxidation from animal and vegetable fats and oils by refining processes.

Bakery products, especially those prepared to last a long time between baking and final consumption, are sensitive to oxidation in proportion to their content of fats and oils. Bread and cake are generally consumed within a few days after baking and seldom reveal rancidity. The change in flavor and consistency called "staleness," however, is probably partly due to oxygen, although this cannot be stated as a fact. Crackers and small sweet cakes which are put up in packages develop rancidity and "staleness" within from one to six months, the time depending on their composition and the conditions of storage. "Soda crackers" containing very little fat keep best while those containing large amounts of butter, other delicate fats and egg are comparatively short-lived.

Candy containing butter and other fats which become rancid is subject to oxidation spoilage, often becoming unfit for consumption within a few weeks after manufacture. Hard candy and other varieties which are practically pure sugar combinations are almost immune from oxidation changes. Flavors in such candies especially when delicate essential oils are used may be changed somewhat. Chocolate candies acquire a stale odor and taste on long exposure which is at least partly due to oxygen. Damage to chocolate from this cause is large in the aggregate. The spoilage would be vastly greater but for the fact that chocolate fat or cocoa butter is one

of the least oxidizable of the fats. Even when partially oxidized or made rancid, the flavor is not nearly as unpleasant as that of other rancid fats.

Oxygen plays a comparatively small part in the spoilages and deteriorations of fermented and distilled liquors. These products are necessarily stored in comparatively air-tight containers and very little oxygen gets to them. Most fermented liquors are subject to the action of acetic acid bacteria upon their surfaces. These bacteria require oxygen for carrying on ther work and therefore the growth may be arrested if desired by simply sealing the container. Oxygen has a positive beneficial action on distilled liquors, acting to modify their flavor during the ageing process to which most liquors are subjected.

Non-alcoholic beverages are stored chiefly in glass and oxygen has very little chance to get in contact with them. Even if it does, very little damage ensues except to essential oil flavors. Citrus fruit flavors are particularly subject to an oxidation change which results in the essential oil acquiring an odor like turpentine.

The study of oxidation changes is a very much neglected field in food preservation. Many obscure spoilages often will be clarified when the possibility of an oxidation change is considered. Realization of the importance of oxidation in food preservation is resulting in important changes in methods and further development along this line is in immediate prospect.

Spoilage by Light

We are not used to thinking of sunlight as an agency of destruction and yet by observation we find that it is

capable of initiating many chemical reactions that assist in the spoilage of foods. As a matter of fact, light waves —particularly the short, invisible rays called ultra-violet —are intensely active and very few organic substances can stand long exposure to intense light without some changes in composition.

Damage to stored foods by light is of very little practical importance when compared with the damage done by such agencies as micro-organisms, insects, etc. Storage of foods demands a container, whether a grain elevator or a tin can, and most food containers are practically impervious to light.

We may consider cereals and legumes, among the foods of plant origin, as entirely immune from the effects of light. Spoilage of nuts may be hastened by the effect of light rays in accelerating the development of oxidation and rancidity. No authentic instances of this action can be cited, however.

Spoilage of fruits, vegetables and edible fungi may be influenced in isolated instances by light but these instances are rare and of little importance. They are probably related to enzyme action or oxidation.

Among the ordinary foods of animal origin, light is equally unimportant. Light probably influences the rancidity of butter when it acts in conjunction with air. Light seldom comes in contact with foods of this class in sufficient intensity or for a long enough period to cause material damage.

Among prepared, refined and manufactured foods the light damage is restricted to those products that are exposed in glass containers. Of these, edible oils or

"salad" oils are probably the most seriously affected. The acceleration of rancidity by exposure to light is so great that one large firm stated prominently in an advertisement that they would not pack their product in glass "for a million dollars."

Bottled beverages, particularly fermented beverages derived from grain, are susceptible to light changes. Some brewers go to considerable expense to put their product in tinted glass bottles for the purpose of shutting off the more active rays of light. The appearance of sediments and cloudy precipitates in beverages has also been attributed to light.

Spoilage in which light plays a part generally develops so slowly as to be almost imperceptible. It is therefore not at all strange that very little is known of many of the changes in which it plays a part. Light is not very important when considered in terms of amount of damage done but it is so often connected with some obscure form of spoilage that no student can afford to neglect it.

Colloidal Changes

Before discussing colloidal reactions and their relation to food spoilage, a few words regarding the nature of colloids will not be out of place. The word "colloid"—the root words of which mean glue-like—was invented by a chemist to describe a class of substances having the general characteristics of gelatine or glue. The meaning of the term has broadened with use and now refers to dispersed matter in general, the particles of which vary in size between the molecular state and particles which can be seen under an ordinary high-powered

microscope. Many substances appear in all three states of dispersed matter, molecular, colloidal and mechanical division. Gold for instance can be molecularly dispersed by dissolving its compounds, such as gold chloride, in water and mechanically dispersed into any desired size of particle by various means. Under certain conditions, gold can also be made to appear as beautifully colored colloidal solutions in water and is also made to disperse as a colloid in melted glass, forming the "ruby" glass of commerce. In spite of the extremely high specific gravity of gold, its finer colloidal particles remain suspended indefinitely in water.

In general, our foods are composed almost entirely of colloidal substances in very complicated inter-mixture. It is fortunate for us that these complex mixtures are comparatively stable. However, some colloidal changes occur which deleteriously affect foods and it is with these changes that we are concerned here.

Colloidal changes may make themselves evident in food products in several ways. They may cause changes in consistency, flavor and appearance sufficient to completely destroy the value of the product as food. In beverages, the most usual colloidal change is the appearance of a cloudiness or sediment caused by the gathering of small particles into particles of larger size.

A great many colloidal changes go on in food substances which are not of interest to us here because they are not positive causes of spoilage. Many of these changes have no visible effect on the food. Others may be actually beneficial.

There are very few spontaneous colloidal changes of a

deleterious nature in our natural foods of either plant or animal origin. Food spoilage from any of the causes which we have previously discussed almost invariably involves changes of colloidal state. These changes alone may be sufficient to condemn the food but usually other changes, more disagreeable and damaging occur, which over-shadow them in importance.

In the realm of manufactured foods, considerable trouble is experienced with undesirable colloidal changes. Manufacturing methods lack the slow, sure steadiness of nature's growth process and therefore colloidal mixtures built up by man-made methods do not have the equilibrium of natural products

The baking industry furnishes one of the most important examples of the effect of colloidal changes on the keeping qualities of foods. Gluten, starch and several other constituents of bread are all colloidal in nature and changes involved in the transference of water from one constituent to another within the product have been shown to have an important bearing on the development of "staleness." The confectionery industry also has its colloidal problems. Chocolate is essentially a colloidal suspension of sugar and the normal cocoa constituents in cocoa fat or "cocoa butter." Changes in temperature and humidity produce changes in the appearance and consistency of the chocolate, which may be classed as colloidal. One of the most important of these changes is the "graying" of chocolate in which the crystallization of some of the cocoa butter constituents also plays a part.

In the field of liquid foods and beverages we have our most serious trouble with spontaneous colloidal changes.

These changes usually involve the coagulation of colloidal particles and the consequent formation of a visible sediment. The coagulation of these particles may come about through changes in temperature, the addition of another constituent, the loss of a constituent through evaporation and other causes.

In distilled liquors all colloidal matter is effectively removed in the distillation process. Therefore in this class of beverages we do not have trouble from dediments unless constituents containing colloids are added after distillation. In fermented liquors, wines and beers, however, it is a different story. During the normal fermentation of a wine or beer, colloidal substances derived from the fruit or grain used are coagulated and go to the bottom of the fermenting vessel as dregs. Sometimes all these colloids are not coagulated during the fermentation and remain to come down as an unsightly sediment after the beverage has been filtered and bottled. In wine the presence of a little sediment is not considered a serious drawback but in beer it is considered a sign of poor brewing. The sediment or cloudiness which sometimes develops in beer has been found to consist of protein substances. The enzyme pepsin, which has the property of dissolving proteins is often added to beer for the purpose of rendering these proteins soluble. Beer thus treated does not get cloudy even when kept directly on ice.

Unfermented beverages containing water extracts of plant substances are very likely to throw down sediments consisting of coagulated colloids. We have all noted the cloudiness and sediment that develops in coffee

and tea when standing for a few hours. Other plant extracts act similarly. For this reason no liquid tea or coffee extract has ever been commercially successful.

Fruit juices are also very prone to develop unsightly sediments. Successful methods for packing citrus fruit juices still remain to be developed, largely on account of inability to get around undesirable colloidal changes.

We must not get the idea that all sediment in liquid foods and beverages comes from spontaneous colloidal changes. Often we find this condition caused by microorganisms or some foreign substance derived from the container or outside source. Investigation with the help of the microscope will usually get at the real cause.

Temperature Changes

The temperature of storage has a profound effect on almost every kind of spoilage which we have discussed. We know that the growth and development of insect life is greatly affected by temperature conditions. Most insects have comparatively narrow ranges in which they multiply and fulfill their normal functions. Microorganisms are even more sensitive to temperature conditions. There are also certain narrow ranges of temperature at which enzymes exert the fullest activity. Outside these ranges they either remain dormant or become permanently inactive. True chemical changes of all kinds increase in intensity as the temperature rises. In general, chemical changes double in activity with each rise in temperature of eighteen degrees Fahrenheit.

These, however, are changes in which temperature plays a more or less indirect part. We are concerned

here with spoilage brought about directly by the effect of temperature changes. It will be convenient here to discuss first the changes brought about by excessively low temperatures and then those produced by temperatures higher than normal.

Damage to food products from low temperatures does not make itself evident until the freezing point of water has been reached. For this reason the foods that suffer most from low temperatures are those containing comparatively large amounts of water. Therefore we need give but little consideration to the effect of low temperatures on the dry cereals, legumes and nuts. Nuts containing water, however, are as sensitive to freezing as other watery foods. Coconuts, which contain a watery fluid or "milk" are particularly subject to damage by freezing. When frozen, the shell is ruptured sufficiently to allow the ingress of micro-organisms. Complete spoilage soon follows.

Foods in the vegetable class contain large quantities of water and are therefore almost universally subject to freezing spoilage while in the fresh state. During freezing, the water within the cells of the vegetable forms ice crystals and when these afterwards melt, the water does not go back to its original state but evaporates or remains to make the vegetable a flabby, useless mass. Where utility as food is not entirely destroyed, the way is left open for the inroads of the myriads of bacteria, yeasts and molds which are always waiting to seize such opportunities.

Dehydrated vegetables are not as a class sufficiently affected by freezing temperatures to merit much consid-

eration. Small physical changes undoubtedly take place but these are not sufficient to affect the marketability of the food.

Canned vegetables are affected in quite a different manner from either the fresh or dehydrated products. Water is always present in large amounts as in the fresh state but the character of the vegetable is so changed by the canning processes that the effect of freezing is entirely different. The effect of freezing is also mitigated by the fact that the container usually is entirely filled with a watery liquid which, on account of dissolved sugars, salts, etc., is proof against freezing, to a limited extent. The most frequent results of the freezing of canned vegetables is softening and sometimes disruption, with a resulting cloudiness of the liquid contents of the container. The food value of the product is seldom greatly affected but the market value suffers very frequently. Another result of freezing may be to disrupt the container or at least strain the seams or closure to such an extent that micro-organisms and other agencies of spoilage can get in their work. This of course results in complete destruction.

The fruits suffer quite as much from freezing as do the vegetables and in identical ways. No fresh fruit can withstand freezing and remain in a merchantable condition. Canned fruits behave similarly to canned vegetables under low temperatures but can resist a somewhat lower degree of cold without freezing on account of the fact that the natural fruit sugars and the added sugar tend to lower the freezing point of the liquid portion of the contents of the container.

Flesh foods resist freezing damage to a much greater degree than do the vegetables and fruits. This is probably due to a certain extent to their fibrous structure. No one will maintain that frozen meats and fish after thawing are identical with these products in a fresh state but the loss of desirable qualities is so small that freezing has become one of the leading methods of meat preservation.

In frozen milk and cream the butter fat globules have a tendency to coalesce and separate upon thawing. Otherwise there is very little perceptible change. The expansion of milk in bottles by freezing is likely to break the bottle or else force its way out through the top. Other dairy products are usually handled in such a way that very little trouble is experienced through freezing.

Eggs in the shell must be carefully guarded against a too low temperature. Freezing causes the shell to break and this alone causes the commercial value of the egg to be destroyed unless they can be broken immediately and put up for the baking trade as frozen eggs in cans. This product—frozen eggs in thirty pound tin cans—has become a very large article of commerce. The eggs are broken and the whites and yoke separated by hand in some instances. If desired, the whole egg may be mixed together and frozen. The eggs are filled in cans and the entire contents of the can frozen in one solid block. These are thawed out by the user by immersing in water overnight. When thawed, the eggs have somewhat different characteristics from freshly-opened eggs, but there is not enough difference to affect their use for baking purposes.

Among "manufactured" foods we find some products that must be protected from freezing. The refined carbohydrates—sugars and starches—are of course immune on account of the absence of water. All of the edible oils solidify when cold but this fact is allowed for and when they melt again, they are unchanged.

Bakery and confectionery products are for the most part immune from freezing on account of their low water content. Confections which contain any considerable amount of water also contain sugar, which protects the water from freezing except in the coldest climates.

Among the beverages, distilled liquors are also immune, their high alcohol content preventing freezing very effectively. Beverages of low alcoholic content and those without alcohol often freeze with disastrous result to the container. When a liquid containing alcohol partly freezes, the alcohol content of the liquid portion will be found to have become concentrated in proportion to the amount of water that has changed to ice. If the alcoholic liquor is drawn off and the ice melted, the resulting liquor will be found to contain little or no alcohol.

Non-alcoholic beverages resist freezing in proportion to the amount of sugar and other soluble substances they contain. A very few degrees below the freezing point of water are usually sufficient to freeze them, however, as the soluble matter usually does not exceed ten or twelve per cent. Beverages marketed in the form of syrups are highly resistant to freezing on account of their high sugar and lower moisture content.

Prepared foods consisting essentially of oil and water emulsions are particularly sensitive to freezing. Usually

the emulsion is broken entirely and its ingredients at least partly separated. Manufacturers of prepared salad dressings suffer a great deal from this cause.

When we start to consider the spoilages initiated by high temperatures, we find that in most of them the temperature plays only an indirect part. Since we are discussing elsewhere the effect of the direct agencies of spoilage on specific classes of foods, it will be sufficient here to point out the salient effects of temperature in accelerating these direct causes of spoilage in general.

Destruction of foods by animal life—mammals and birds—is affected very little by ordinary temperature changes. Rats and mice, the principal offenders, seem to be able to exist in all but the coldest climates. We find, however, that insect life has comparatively short ranges of temperature in which to multiply and function. These temperature changes vary considerably for different species, but in general it may be set down that the higher the temperature, the more danger of infestation by insects. Most insects are able to exist for long periods in a dormant state when temperature conditions are unfavorable. This possibility must always be recognized when dealing with foods that have been stored at a low temperature and are then brought out into conditions suitable for the growth of insects.

Micro-organisms also have narrow ranges of temperature in which they can act. Unfortunately these temperature ranges vary greatly, some being as low as ice box temperature and others as high as 130°F. We also find some species of micro-organisms able to grow sufficiently well at a comparatively wide range of tempera-

ture to make the foods upon which they grow unfit for consumption. The common blue mold is a good example of this kind of organism.

Each enzyme has an optimum temperature at which its activities reach a maximum. These optimum temperatures are usually comparatively high. Most enzymes are able to cause considerable change in foods, other conditions being favorable, at ordinary room temperature (about 70°F.).

Chemical changes of all kinds are stimulated by heat. Oxidation, colloidal changes, the action of light and the reactions of foods with metallic containers are all hastened greatly by a rise in temperature. When foods subject to such changes are to be held for long periods, the knowledge that the speed of chemical reactions is reduced one-half for each 18°F. drop in temperature, will instantly suggest storage at a low temperature.

Spoilage by Extraneous Water

Frequent mention has already been made of the great influence of the natural water content of foods on their keeping qualities. We have noted that almost every cause of spoilage is accelerated by the presence of natural water in foods. In food preservation we have also to contend with extraneous water which may gain access to foods and not only exert the same effects as the natural water but other effects as well.

Extraneous water usually gets into foods in one of the following ways—rainfall on temporarily unprotected storage space; sea, lake or river water during boat trans-

portation; defective plumbing in storage buildings or as a result of attempts to put out a fire. In the latter case, the conditions are likely to be complicated by fire and smoke damage as well.

No matter how the water gets into the foods, the result is the same. Water soaked cereals, unless promptly dried, either germinate or develop micro-organisms. Insect infection is another possibility. The same damage is done to dried legumes. Nuts are practically certain to become moldy, whether shelled or unshelled. Some may germinate.

The fresh vegetables, being naturally provided with a high water content, can stand contact with extraneous water for a short time. Internal enzymic changes and spoilage by micro-organisms soon occur, however, unless conditions are changed promptly. Dried vegetables are rapidly attacked by molds and bacteria as soon as water gains access to them. Immediate re-drying is the only method by which they can be saved.

Most fruits can stand temporary contact with water on account of the fact that their rinds contain waxy matter which makes them water resistant. Spoilage by molds and yeasts almost certainly follows prolonged contact, however. Fruits vary greatly in their resistance to spoilage by water—firm fruits, apples for instance, are very resistant while those that are soft and pulpy, such as cherries and grapes, soon break down and admit spoilage micro-organisms.

Dried fruits which become water soaked develop yeasts and molds within forty-eight hours and must be redried within that time if they are to remain fit for con-

sumption. Water soaked dried fruits are also likely to swell and burst containers such as boxes and barrels.

The edible fungi—yeast and mushrooms—are very susceptible to extraneous water, enzymic activity and the growth of foreign micro-organisms being started with disastrous results.

Flesh foods are usually so well guarded against extraneous water that very little damage is ever experienced. When water is kept in contact with fresh flesh, whether meat, fish or fowl, for a prolonged period the effect is to dissolve the soluble matter and soften the tissues. Later the growth of micro-organisms is accelerated, causing putrefaction, if not checked. Salted and cured meats will mold if allowed to get wet. If the exposure to water is severe and prolonged, the preservative substances become so diluted that putrefying bacteria are able to grow.

Small amounts of water added to milk or cream has little effect on its keeping qualities. Large amounts of course render them below legal standards and therefore unsaleable. Butter can stand temporary immersion in clean cold water for several hours without loss of food value. Long exposure washes out some of the solid constituents and also accelerates the growth of bacteria. The constituents of cheese are largely soluble or readily suspendible in water. Foreign water therefore injures cheese as well as starts undesirable biochemical changes.

Eggs in the shell are damaged by immersion in water for a very few minutes. A dried mucus over the surface of the egg is washed off, leaving the way open for bacteria and molds to penetrate the porous shell. Dried eggs

when water damaged rapidly develop myriads of bacteria, yeasts and molds.

The highly refined sugars are probably the most readily damaged of all food by extraneous water. All of them are highly soluble and if enough water comes in contact with them, they are dissolved and lost. If the water is only sufficient to moisten the sugars—molds, yeasts and bacteria soon develop and greatly lower the value of the sugar, if they do not destroy it altogether. Syrups in tight containers when diluted by water become susceptible to yeasts, molds and spoilage. Usually alcoholic fermentation develops rapidly.

All soluble carbohydrates may be expected to act like the sugars when in contact with extraneous water. The insoluble carbohydrates—the starches and celluloses—act quite differently. These substances, when accidentally wetted, may be dried again almost without change, if the operation is done intelligently. If water remains in contact with the insoluble carbohydrates for more than a few hours, molds will almost certainly develop. This development will take place more quickly in a poorly refined product than in one highly purified for the reason that a more "balanced ration" is available for the mold.

Water which comes in contact with edible oils may usually be drained off without damage. A little will remain suspended in the oil in fine droplets, but these can be filtered out or driven out by heating under vacuum. Oil which is allowed to remain in contact with water for several days is likely to develop free fatty acids. In the reaction by which vegetable and animal oils are converted to fatty acids and glycerine, water is essential.

Only a small amount of water is necessary to cause condesirable damage, as one part of water is sufficient to react with from ten to fifteen times its weight of oil.

Bakery products, the value of which largely depend on appearance and crispness are ruined by contact with very little extraneous water. If the water does not irretrievably damage the product by destroying appearance and consistency, it soon assists in the development of molds, "wild" yeast and bacteria which finish the job of destruction with thoroughness.

Confectionery products are even more susceptible to water damage on account of their high sugar content. A very small amount of water not only destroys the appearance, shape and consistency of confections but renders most of them almost ideal breeding spots for molds and yeasts.

Extraneous water which is allowed to get into fermented liquors may disturb the equilibrium established during the fermentation which may be very damaging to the product. Of course a great deal of water will destroy the value of liquors of any kind simply by diluting them.

Fire Damage

It is hardly necessary to say that no food is exempt from fire damage. Fire damage may take any one of several forms. The food may be actually consumed by the flames, or become so charred and carbonised by heat that its value is entirely destroyed. It may absorb products of combustion, such as cinders, smoke, dust, etc. from the fire which may destroy all or part of its value. And, indirectly, it may be so so saturated with water by

efforts to put out the fire that it becomes subject to the many spoilages described under "Damage by Extraneous Water."

It is obvious that any food product which is partly burned or carbonized is unfit for consumption and that no food is exempt from the possibility of such damage. It is quite apparent also that no food products with the exception of smoked meats and fish and foods in hermetically sealed containers, can stand contact with the products of combustion without damage. It is therefore quite useless to go into detail about the effect of fire damage on the various classes of foods. However, some comments on the behavior of some foods in fires may be of value.

Dry cereals and legumes burn very much the same as wood in a similar state of division. The products of combustion are practically the same in cereals but differ somewhat in legumes. Decomposing proteins and—in the case of some fatty legumes—burning oil, cause a particularly heavy smoke with a disagreeable odor. The same is true of nuts, which also are high in protein and oil. In all fires in which finely divided dry food products are concerned, the danger of dust explosions is very great. Flour mills are very susceptible to these explosions.

Fresh fruits and vegetables will not burn until sufficiently dried by the heat of the fire. When dry, they behave like wood or other carbohydrate material. Canned fruits and vegetables, in fact all canned goods, are either exploded by steam pressure developed by the heat, or their flavor and appearance is destroyed even if the container is not affected.

Animal foods of all kinds on account of their high protein content give off very disagreeable odors when burning. They are also as a class very susceptible to odors from a distance and are likely to become damaged by comparatively little exposure to smoke.

It is quite useless to go into details about the characteristics of the refined and "manufactured" foods when burned. All of them are derived from either animal or vegetable sources and their behavior may be predicted quite accurately from a rough knowledge of their chemical composition. It will be sufficient here to call attention to the severity of animal and vegetable oil fires and those in which high-proof alcoholic liquor have a part.

Damage Caused by Humidity

We have already discussed at considerable length the various ways in which natural water and extraneous water injuriously affect foodstuffs. In addition to the damage caused by water in these forms, there is still a third way by which water can get into our foods to their detriment—by way of the air in the form of vapor. Water vapor is an ever present constituent of the air. Even in the dryest desert air, water vapor is present. The amount of water vapor in a given volume of air depends on the temperature of the air and its opportunity for coming in contact with water or wet surfaces. The ability of air to hold water vapor or, more correctly, the ability of water to give off its vapor to the air, is dependent solely on temperature conditions. Air in the Sahara Desert may have a temperature of 90°F. and contain only twenty percent of the water vapor it is

capable of holding at that temperature. Air in the rainy season in the tropics at the same temperature may contain ninety or even one hundred percent of the amount it is capable of holding. The amount of water vapor in air expressed in percent of the amount that air is capable of holding at the same temperature, is termed the "relative humidity" of air. The total amount of water vapor expressed in absolute weight units per absolute unit of volume, for instance—as grains per cubic foot, is known as the "absolute humidity." Both these terms are of the greatest importance to those interested in the manufacture, storage and marketing of foods and should be thoroughly understood.

The ability of air to hold water vapor varies greatly. Air, which at noon on a summer day contains only fifty percent as much water vapor as it will hold when saturated (in other words which is at fifty percent relative humidity) will cool enough by evening to throw out part of its water vapor in the form of dew on grass or on anything else which cools quickly. The formation of dew is simply the indication that the cool air is unable to hold all the moisture it contained while warm. All the moisture above that amount required to saturate air at the low temperature must necessarily take the form of water, usually as dew, fog, or mist.

Such phenomena may not appear to be related very closely to food preservation, but upon consideration we find that nearly all foods are subject to damage by adverse humidity changes and that in many cases damage by humidity changes is the most frequent form of trouble.

The cereal foods and the dried legumes are quite re-

sistant to the effect of moist air. In extreme cases, where the humidity reaches eighty to ninety percent these foods may absorb enough water to start the growth of micro-organisms. Enzyme changes may also be initiated.

Nuts are more likely to suffer from these changes than cereals and legumes. An increase in moisture content of one or two percent is enough to start mold growth with consequent rancidity and total spoilage. Nuts in the shell are more resistant than the shelled meats.

Fruits and vegetables suffer similarly from excessive humidity, principally on account of the increased activity of micro-organisms under this condition. Insect and enzyme spoilage is also accelerated in many instances.

Fresh meats, milk and eggs are little affected by humidity changes under practical conditions. The normal water content of these products is naturally so high that a little more usually makes no difference. The tendency of excessively high humidity, however, is to increase the likelihood of spoilage. Salted meat and fish and dehydrated milk and egg products are more seriously affected by humidity conditions. All these products tend to absorb moisture when the relative humidity of the air is high with the result that molds often grow and other undesirable chemical and biochemical changes take place.

All hermetically sealed food products are of course immune from humidity changes. This is one of the very desirable features of packing food in metal or glass containers.

Many bakery products, especially those which must remain crisp, are injuriously affected by high humidity. The principal damage is the loss of crispness, although

some products may take up enough moisture to encourage mold growth. Candy of all kinds is extremely sensitive to humidity conditions. In chocolates the gloss is destroyed and in some cases the entire coating turns a dirty gray. Hard candies are sticky and often crystallize or "grain." Damage of this kind is so severe that many candies cannot be sold in warm, moist countries.

Refined carbohydrates—the sugars and starches—seldom suffer from humidity, partly because of the large volumes in which they are handled. The starches have the ability to absorb comparatively large amounts of water without visible effect and for this reason are often put in products such as baking powder for the purpose of acting as a sort of buffer between moist air and some sensitive ingredient. Highly refined cane sugar takes up very little water even from very moist air. The presence of invert sugar, a decomposition product of cane sugar, greatly increases its water absorbing capacity. Raw sugars, which may contain several percent of invert sugar, may absorb enough water to start a series of spoilage by micro-organisms.

All beverages, whether non-alcoholic, fermented or distilled, must be kept in tight containers and are therefore immune from the effects of humidity. Distilled liquors when stored in wooden casks, however, furnish an instance worthy of comment. If the room in which the liquor is stored is of high relative humidity, the alcohol will evaporate through the cask faster than the water and the alcoholic content of the cask becomes lower. On the other hand, if the room is very dry, the water will evaporate faster than the alcohol and the liquor

will actually become stronger. Of course the total volume of the liquor decreases in either case.

Damage by Evaporation

We have just discussed the many spoilages caused by the absorption of water from air of high relative humidity. There are also a great many cases where damage is done to food by evaporation of moisture caused by exposure to air of low humidity. Damage by evaporation usually affects the physical condition of a food. In a few instances other causes of spoilage are helped to gain a foothold, but these may beconsidered the exceptions that prove the rule.

Cereals, dried legumes and nuts, being practically water free, do not suffer any damage from dry air. In general, the dryer the air the better these products keep. An exception to this rule is the coconut, which in its whole state is very sensitive to dry air. The dry air causes the shell and finally the meat to crack, allowing yeasts, molds and bacteria to get in and spoil the meat for edible purposes.

Fresh vegetables, fruits and edible fungi all suffer great damage from dry air. The general tendency is for these products to become wrinkled, shriveled or wilted. Most fruits and vegetables are sold on appearance and therefore these spoilages result in great financial damage.

Fresh meats and fish suffer in appearance by surface drying when exposed to warm, dry air but these products are usually so well handled and protected that evaporation is a very small factor in causing spoilage. As in other foods, evaporation causes very serious losses in weight, which is the dealer's loss and the consumer's gain.

In dairy products, evaporation is a negligible quantity in causing spoilage. Milk and cream are protected by the tight containers in which they are transported. Butter is an oily material and therefore not subject to evaporation. Cheeses which are explosed to air develop hard crusts on their surfaces which are very effective in preventing further evaporation. More delicate cheeses are protected by tin foil, metal and glass containers and by other means.

Evaporation is a very serious factor in the ageing of eggs in the shell. Sometimes eggs dry completely in the shell without spoiling in any other way. The amount of evaporation in an egg is accepted as an indication of its age and hence evaporation greatly lowers their commercial value.

Refined sugars and starches are immune from evaporation damage for the simple reason that they contain little or no water. Evaporation may cause crystallization or other objectionable change in syrups but these products are usually kept in tight containers and are therefore seldom exposed.

Bakery products which contain considerable amounts of water—bread and cake for instance—are very sensitive to evaporation changes. Evaporation is the principal factor in "staleness" of these products. Crackers and small cakes which are intended for grocery store distribution are practically dehydrated during baking and therefore cannot be dried further by the dryest air.

Some kinds of candy dry very rapidly and become inedible while others keep best in dry air. Candies of the former class are usually those which contain sugar

crystals individually coated with a syrupy mother liquid. Examples are "fondant" and "creams." Candies which keep well under arid conditions are hard candies, solid chocolates and those candies made of practically dry sugar compressed into tablets.

Beverages, whether alcoholic or non-alcoholic, all have water as a base and are therefore subject to loss by evaporation. Most beverages are protected from such loss by tight containers. Attention has already been called to the behavior of alcoholic liquors stored in wooden casks. Other liquid food products are also subject to evaporation losses when stored under similar conditions.

All the evaporation losses thus far discussed have been those caused by loss of natural water from foods. Another very serious form of damage arises from the evaporation of flavoring substances from foods. Practically every food contains flavoring substances, which affect the sense of smell. Most of these compounds may be classed as volatile or essential oils. In order for these oils to exert an influence on our sense of smell, it is essential that particles or molecules of the oil be given off into the air. When a food is openly exposed, these molecules fly away never to return. It takes but a very small quantity of essential oil to produce an odor sensation but a constant loss of flavor molecules day after day soon causes a weakening of the flavor of the food itself. When the time comes for the food to be consumed, its characteristic flavor has evaporated and it is said to be "stale" or "flat."

Cereals, legumes and nuts suffer very little from flavor

evaporation, probably because their flavors are not very volatile. The flavor of fresh vegetables and fruits probably is lost more through chemical change than evaporation, although the latter cause no doubt plays a part. The same is true of the animal food generally. It is in the manufactured foods that we find the greatest trouble with flavor evaporation. Bakery products and confectionery are particularly susceptible. The skill of man has not yet approached nature in blending flavors into foods and doubtless we will never discover all the secrets of holding natural flavors in our manufactured foods. A great deal of improvement in flavor combination and application is possible and we should be heartily ashamed of the little progress so far made in this direction.

Miscellaneous Chemical and Physical Spoilages

The physical and chemical changes which we have just discussed include most of the instances of food spoilage that have been studied. Occasionally, however, chemical and physical spoilages occur which apparently defy classification. Usually such spoilages take place in foods which have been put through strong heating processes such as roasting, sterilization, etc. It will be sufficient here to give a few examples.

Peanuts which have been roasted and packed in hermetically sealed containers give off a gas containing hydrogen sulphide which does not seem to affect the flavor of the nut itself but causes a very disagreeable odor when the container is opened. Bacterial and enzymic causes for this reaction are eliminated by the heat of

roasting and the dryness of the product. Oxidation and humidity cannot be the cause because the gas is evolved in hermetically sealed containers in an atmosphere of inert gas. The reaction is apparently a spontaneous decomposition of sulphur-containing proteins but the exact mechanism of the change is a problem still awaiting solution.

Similar evolution of gases takes place in canned fish, lobster, crab-meat, corn and other products sterilized by heat. In these products, however, water is present and the reason for the decomposition is more apparent. Still the problem cannot be said to be solved until damage is stopped and hundreds of canners can testify that we are a long way from this happy condition.

Another peculiar case of spontaneous evolution of gas is found in roasted coffee. Fresh roasted coffee starts giving off a gas consisting of carbon dioxide and monoxide immediately after roasting. These gases continue to evolve for several days, the length of time depending on the fineness of the grinding of the coffee. The gas comes off slowly from the whole roasted bean but very rapidly when the bean is finely ground. As in the case of peanuts, micro-organisms and enzymes are eliminated as the cause by the high temperature of roasting. The reaction also goes on in the absence of oxygen and water vapor. The writer's theory is that the gases are formed during the roasting process, but cannot escape from the cells of the coffee and are therefore held under pressure. In time they diffuse through the cell walls and if the coffee is held in a hermetically sealed container, pressure is built up. After the pressure between the interior of the coffee cells and

the atmosphere of the container has become equalized, the evolution of gas ceases. This theory seems to satisfy the known facts but of course requires confirmation by experimental work.

During the Great War, the United States Bureau of Fisheries recommended the canning of dog-fish and other members of the shark family under the name of "grayfish." This was apparently very wise advice and many canners acted upon it. Unfortunately it was discovered too late that the flesh of sharks contained urea, which decomposes in time to ammonia, spoiling the flavor of the product and swelling the container. This condition was discovered and remedied too late to prevent the loss of thousands of dollars to the packers. Needless to say, grayfish as a food product has lost caste and it is doubtful if it will ever be packed in large volume until other fish are not available.

These instances will be enough to show that chemical and physical causes of spoilage are by no means thoroughly explored and that such problems form a very fertile field for the investigation of scientists and technical men.

CHAPTER VI

CAUSES OF FOOD SPOILAGE (CONTINUED)—CONTAMINATION WITH FOREIGN SUBSTANCES

Contamination with Metals—Tin—Copper—Zinc—Lead—Arsenic—Air Floated Dust.

In our discussion of the causes of food spoilage, we have mentioned instances where destruction of food was accompanied by contamination of the undestroyed portions by animal and insect excrement, by products of the growth of micro-organisms and by other injurious substances. It is obvious that foods may become accidentally contaminated with almost every kind of known matter, both injurious and non-injurious. It is conceivable, also, that two perfectly wholesome food substances might become mixed with each other in such a way that the combination would be valueless. The remedy for contamination of this class is so obvious that it hardly merits discussion. Here we are concerned with more insidious contaminations such as arise from contact of the foods with metallic containers, poisonous chemicals, air-floated dust, etc.

As our food supplies tend to be handled more and more in large factories and to be stored and packed in metallic containers, the problems of metallic contamination have

become forced upon the attention of the food chemist and physiologist. He has been forced to pass upon such questions as the amounts of certain metals that can be tolerated in foods, the effect of ingesting comparatively large amounts of metallic salts upon the human body and other questions equally important. Many of these questions still remain in dispute but a great deal of data bearing on the origin and extent of metallic contamination has been accumulated. From these data government authorities have been able to establish reasonable limits for metallic contamination and only the careless or incompetent manufacturer is unable to keep within these limits.

The metals most frequently found in foods are iron, tin, copper, zinc, lead and arsenic. Some of these are found normally in foods in their simplest form but usually in very small amounts. Iron is a constituent of all food. It occurs in the soil and in the water from which it is transferred to plant life. From plants it enters the bodies of animals in the blood stream of which it plays a very important part as a constituent of the haemoglobin. Iron also gets into our food from kettles, storage tanks and other equipment of the food factory and from metal and part metal containers of which iron or steel is the principal constituent. It is seldom, if ever, directly injurious to the consumer. On account of the fact that many of its chemical compounds are black or colored, it frequently ruins the appearance of such foods as canned meats and fish, corn, sweet potatoes, and others. Discoloration in these products is caused by the formation of red and black iron oxides and black

iron sulphide from oxygen left in the container and from hydrogen sulphide given off by some of the foods. Iron—and other metals also—cause a bleaching action on some canned foods when acted upon by organic acids. The principal sufferers from this cause are canned berries and other colored fruits and some vegetables. Another disagreeable feature of this reaction is the formation of hydrogen gas in tight tin fruit containers. The gas causes the can to swell and leads the consumer to believe that fermentation has taken place, although the actual food value of the product may not have been injured.

The only tin contamination worthy of comment in foods is that arising from the packing of foods in "tin" cans. A "tin" can is in reality a steel can coated inside and out with a thin coating of tin. The inner coating is in constant contact with the contents of the can often for a year or more and it is therefore not remarkable that considerable amounts of tin are absorbed by many foods. The principal offenders in this respect are the strongly acid fruits and a restricted class of vegetables, which include rhubarb, asparagus, pumpkin and string beans. Rhubarb frequently takes all the tin from a can, leaving the black iron exposed. A great amount of work has been done in an effort to find out if the tin dissolved in foods has a detrimental effect on the human system. The subject is still frequently agitated but the tentative conclusion arrived at is that tin salts in moderate amounts are not harmful. The United States Government has set the limit at three hundred parts of tin per million parts of food and this has worked out very satisfactorily. Copper, zinc and lead are most frequently

found in foods as a result of the use of containers, piping and other utensils made wholly or in part of these metals. At one time copper salts were extensively used in coloring canned green peas, pickles and other food products in which a green color is desired, but this use has been forbidden by food laws and is now seldom seen.

Small amounts of copper, and other metals also, may act as catalyzers to accelerate chemical reactions such as oxidation. The development of rancidity in dried milk and the spoilage of edible oils have sometimes been found to be due to the presence of small amounts of foreign copper.

Pure metallic copper is very resistant to the action of most food substances but when a copper kettle or tank is left exposed to air for several hours or days, its surface becomes coated with a film of copper which comes off quite easily. This is the most frequent cause of contamination from the use of copper utensils.

Zinc is frequently used as a coating for steel (galvanizing) and as such is often the cause of contamination in foods. Zinc chloride is a chemical used largely as a solder flux and it also becomes a source of zinc contamination. Gelatine and egg albumen, which are frequently dried on zinc coated trays, are often found to contain excessive amounts of zinc. The United States Department of Agriculture has set the limit for zinc contamination in food at one hundred parts per million and any amount in excess of this is held to be injurious to health.

Lead at one time was frequently found in foods but medical propaganda regarding the dangers of lead

poisoning has discouraged its use for piping and for containers in food manufacturing plants to such an extent that a case of lead contamination is now rare. The United States Government limit for lead in foods is twenty parts per million and cases where this is exceeded are now almost unknown.

Arsenic is an almost universal constituent of foods but the normal amount is so small as to defy detection. A little still finds its way into foods through the use of mineral acids in refining processes and in other more or less mysterious ways. The United States limit for arsenic is 1.4 parts per million and even this minute amount is seldom exceeded.

A very fertile source of contamination of foods are finely divided dusts of various kinds carried by the air. So serious is this trouble that in some cases food manufacturing plants have to be moved or expensive air filtering and washing devices installed to prevent it. Any solid matter may be reduced to dust and carried by the air and therefore it is quite impossible to classify here the almost innumerable kinds of dust.

The dusts most often causing trouble in food plants are the ordinary street dust, soot from chimneys, flues, locomotives, etc.; and flue dust from smelters and chemical plants.

The foods which suffer most from dusts are those which must be of a uniform light color. These include flour, sugar, dried eggs and milk, desiccated coconut and numerous others.

In addition to causing an unsightly appearance in foods, dust particles may be the indirect cause of spoilage

by carrying living micro-organisms. This is particularly true of street dust and all other kinds of dust that originate from the soil. In some foods, milk for instance, infection through dust particles is the common way in which spoilage gets a start.

CHAPTER VII

FOOD PRESERVATION METHODS AND PROCESSES

Classification of Methods—Simple Storage—Effectiveness Against Causes of Spoilage—Storage of Cereals—Legumes—Nuts and Oil Seeds—"Vegetables," Fruits, Foods of Animal Origin—"Manufactured" and "Refined" Foods.

We are now acquainted in a general way with the causes of spoilage and their effects on the various classes of foods. Our next task is to classify the methods and processes of food preservation and show how they can be used to counteract the spoilage of foods.

The story of the development of food preservation methods is as old as the story of man. It undoubtedly begins with the storage of seeds and grains in crude store houses as a protection against birds, animals and the weather. Later the preservative effects of cold, dehydration and salt were discovered and other methods gradually followed. As modern developments, we have artificial refrigeration and the enormous canning industry built up on the principles of hermetic sealing and sterilization. No effective method has been discarded and we find to-day many of the ancient processes practically unchanged and more widely used than ever. Other old methods have been modified and combined with newer ones and their effectiveness greatly increased thereby.

For our purposes, food preservation methods may be classed as follows:

1. Simple Storage
2. Refrigeration
3. Dehydration
4. Chemical Preservation
5. Preservation by Fermentation
6. Hermetic Sealing
7. Sterilization

Each of these divisions has several sub-divisions which will be discussed when we take up, separately, the various preservation methods. In practice, two or more preservation methods are often used in combination where a single method is not efficient. For instance, fruits preserved with sugar are often hermetically sealed and sterilized. Thus three preservation methods are combined to preserve a single product and each of these methods contributes important keeping qualities. The sugar acts to prevent the growth of many micro-organisms. The sterilization process kills the remaining organisms that are likely to develop in such a product. Hermetic sealing protects from contamination by fresh micro-organisms, and also protects the product from animals, insects, dirt and other extraneous matter and also from the chemical action of oxygen, light and other causes of spoilage.

As we discuss the principal methods of preservation we will show how they are used in combination with other methods and how each one, singly and in combination, is used to preserve the different classes of foods.

Storage

Food preservation presupposes a place of storage. Places of storage must be provided for all foods from the field to the consumers' table. Storage under some kind of shelter may be said to be used in conjunction with all other methods. For the purpose of this discussion, we may take this fact for granted and consider here the protection which storage gives to the various classes of foods without the help of the other methods of preservation.

We may define simple food storage as the method of holding food products in warehouses and in buildings, generally in non-hermetically sealed containers such as bins, wooden boxes and barrels, bags and paper packages, at the temperatures and other atmospheric conditions prevailing in the vicinity. The protection afforded foods by such storage may be summarized as follows:

1. Fairly effective against animal pests.
2. Fairly effective against some forms of insect life but practically useless against others.
3. Practically useless against infection by micro-organisms.
4. Useless against enzyme action except as a means of protection against water (which accelerates enzyme action).
5. Useless against most physical and chemical changes.
6. Effective against most forms of contamination with foreign substances.

It will be seen instantly that storage has very many

limitations and that only foods which have very good inherent keeping qualities can be trusted to this means alone.

Storage of Cereals.—The cereals are almost perfectly designed by nature to stand long periods of storage without injury. The cereal foods are handled in such enormous quantities that it is possible to store thousands of tons in a single building or elevator where an efficient system of inspection can be maintained.

Cereals are stored in the greatest varieties of containers ranging in size from an elevator holding thousands of tons, to the paper carton of rice or breakfast food on the grocer's shelf. Wheat, for instance, is first stored in bags or bins in the farmer's barn. By the farmer it is shipped to elevators at the docks for export, or to the mills for conversion into flour and stock feed. The flour goes to the baker in barrels or cotton, jute and paper bags, or to the ultimate consumer in similar containers. Special wheat products, such as breakfast foods, may appear in still smaller paper containers on the dealer's shelf and in the home. Other cereals are similarly stored during the journey from producer to consumer.

Cereals are relatively free from water and therefore are not frequently spoiled by micro-organisms and enzyme action. They also contain very little oil, which exempts them from rancidity and most other chemical changes.

The principal enemies of stored grains are rats, mice and insects. These pests cause millions of dollars damage in all parts of the world and few storehouses and storage methods are proof against them. The depredations of

rats and mice are fought most successfully with improved building construction, and with the destruction of breeding places—trash, litter, etc. Traps and poisons are used to supplement the first lines of defence. The assistance of the lowly house cat is by no means despised.

Improved building construction, and the destruction of all refuse is also the best method of contending with an invasion of insects. Once insects have gained a foothold in a building in which cereal grains are being stored or handled, they are best fought with fumigation with a poisonous gas or vapor. Sulphur dioxide, carbon disulphide and hydrocyanic acid gases are frequently used for this purpose, the latter most successfully. Even the most sanitary of flour and other cereal mills must be fumigated twice a year. After each fumigation thousands of dead insects are found on the floors, in spite of the fact that often none can be found by casual inspection before the gas is released.

After cereal products have left bulk storage, they are still pursued by rats, mice and insects. Wooden boxes and barrels and paper cartons are very little protection against any of these pests and constant vigilance must be exercised if the product is to reach the consumer in edible condition. Very little intelligence is exercised by distributors to prevent insect contamination, with the result that a very large percentage of the package cereals sold are contaminated by insects. Few consumers notice this, however, unless the insects are very numerous. A great deal of insect contamination of packaged cereals takes place in the retail store, usually the weakest link in the chain of distribution. To get away from spoilage of

this kind, many manufacturers are putting all but the bulkiest products into metal containers, often hermetically sealed. In such packages contamination is impossible unless eggs or living insects are enclosed when the product is packed.

Storage of Legumes.—Dried legumes, principally the commercial varieties of beans and peas, are handled by the same processes and in the same kinds of containers as the cereals. They have in general the same excellent keeping qualities as the cereals and are therefore immune from bacterial, enzyme and most chemical and physical spoilages, unless they are allowed to become wet. They are of course subject to the attacks of rats, mice and insects and these pests are fought by the same methods that have proven successful for the protection of cereals and their products.

Storage of Nuts and Oil Seeds.—Nuts and oily seeds present a more difficult storage problem than the cereals and legumes. In addition to being attacked voraciously by rats, mice and insects, they are also subject to spoilage by molds and by oxidation (rancidity). Most nuts in the shell may be carried in ordinary storage for several months with comparatively little loss. In the case of walnuts, brazil nuts, pecans, and some others, storage in a dry place is actually beneficial. Under this condition the kernels dry out with the result that the nuts are easier to shell and keep longer after shelling. It is during the moist, fresh stage that nuts become contaminated with molds and as a result develop rancidity.

Storage of coconuts must be treated as a special case. Coconuts contain a liquid "milk" which consists of a

watery solution of sugar and mineral salts with small amounts of proteins and fats.

This solution penetrates the flesh of the coconut and furnishes an almost ideal medium for the growth of all kinds of micro-organisms once they gain access to the interior of the nut. As soon as the outside husk—not the shell—is removed from the nut, the water starts to evaporate from the nut meat and is replaced by the milk in the center of the nut. In a few weeks the water has evaporated to such an extent that there is no longer any liquid milk in the center of the nut. Then the nut shell cracks and the bacteria, yeasts and molds get into the meat and finally permeate the entire nut. The maximum time that coconuts can be successfully stored is about three months. If the storage conditions are moist instead of dry, the nuts will sprout, with results as disastrous as those which follow drying out.

Shelled nuts of all kinds rapidly deteriorate in ordinary storage. Rats and mice, insects and oxidation rancidity all take their toll. If the nuts are exposed to moist air or become wet in any other way, molds immediately start to develop. Animal and insect pests are fought with the same methods used for cereals and legumes. Rancidity is more difficult to contend with. The usual remedy is cold storage, although packing with exclusion of air in hermetically sealed metal containers is receiving recognition. These methods will be discussed at length later. The growth of molds may be arrested immediately by drying, if detected soon enough. Usually, however, when mold becomes visible it is too late to preserve the nuts for edible purposes.

Storage of Vegetables.—Few fresh vegetables can be preserved by simple storage alone. A few, such as potatoes, onions and turnips, may be kept for several months but the temperature and atmospheric conditions must almost approximate those of cold storage. Many vegetables are kept through the winter months by farmers by burying in a straw-lined pit below the frost line. In a pit of this kind, the temperature remains low and the air is moist, ideal conditions for the preservation of fresh vegetables.

Dehydrated vegetables, which are becoming increasingly important, are often treated as if they needed no preservation processes other than packing in a wooden or paper container and storing in a dry building. This belief on the part of many packers has been one of the causes of so many failures in this industry. In addition to having all the animal and insect enemies of the cereals and legumes, dehydrated vegetables must contend with spoilage by micro-organisms, enzyme changes and many physical and chemical changes brought about by humidity, light and air. It is obvious that a better system of protection than simple storage is demanded by such sensitive products. Other preservation methods for dehydrated vegetables will be taken up in due course.

Simple storage is very little used as a method of preserving fresh fruits. Very few fruits can be kept for more than a few days without some positive method of control over the conditions which effect spoilage. Some of the more resistant fruits such as apples and pears may be kept for several weeks under ordinary storage

conditions, provided they are not over-ripe and the temperature of the store room is not too high. Such storage is of course very risky and is not used except where better means of preservation are not available.

Some tropical fruits, the citrus fruits and bananas for example, are often stored at ordinary temperatures for short periods to allow ripening to proceed to the proper stage for marketing. These fruits are always under close supervision and this method may be considered more as a process of ripening than of preservation.

Simple storage is very extensively used as a method of keeping dried fruits for long periods of time. This is in spite of the fact that a very large percentage of the fruit so stored becomes infested with insects or overgrown with mold. As a class, however, dried fruits keep better than dehydrated vegetables, principally on account of the preserving effect of the sugars they contain. Insects and mold infestation in dried fruits must be fought chiefly by preventive rather than curative methods. There is very little that can be done with the damaged products other than to convert them to alcoholic liquors, vinegars, etc., or into feed for domestic animals.

Storage of Foods of Animal Origin.—Simple storage is not relied upon to keep any of the foods of animal origin in their natural state. Of course storage is used in conjunction with other methods of preservation, and these methods will be discussed in their proper places.

Storage of "Manufactured" and "Refined" Foods.—We find that simple storage is quite an important factor in the preservation of many of the refined and "manufactured" foods. Sugars, starches and the edible oils

may be stored for months without serious deterioration if protected from the weather and extremely high temperatures and humidity. The sugars and starches, being almost pure dry carbohydrates, are immune from practically all forms of spoilage and may be safely stored for years, if desired. The edible oils, being susceptible to oxygen damage and other chemical changes, cannot be carried as long, but may be safely held in tight tanks for several months, if sound and dry to begin with.

In the more complicated manufactured foods, storage is not a very efficient means of preservation. In the bread and cake baking industries, it is not used at all, the consumer demanding these products fresh from the ovens. The bakers of crackers and small cakes whose products are distributed over wide areas are forced to depend a great deal on storage in the warehouses of dealers and on the grocers' shelves. Spoilage, however, is directly proportionate to the length of time of storage and every effort is made to reduce the time to a minimum.

Stored bakery products are susceptible to the same causes of spoilage as other dry foods. Rats, mice and insects all take their toll. If allowed to get damp, molds are likely to develop. Crackers and cakes containing fats and oils are likely to become rancid, particularly in the warm seasons. This type of rancidity is, almost without exception, due to the chemical action of the oxygen of the air.

All of these cases of spoilage are best guarded against by expeditious handling between factory and consumer and this is the method most generally used. In spite of all the care that is taken, a vast amount of this class of

products becomes insect infested, rancid and "stale" every year.

The manufacturer of confectionery has the same storage preservation problems as the cracker and biscuit baker. His candies may become attacked by insects and rodents and infected with molds and yeasts. Some of them are often oxidized and become rancid and "stale." If exposed to heat and humidity while in storage, some candies become sticky on the surface and others "grain" or crystallize. Chocolate candies under these conditions lose their lustre and become gray.

Almost all confectionery products are highly flavored with natural or synthetic essential oils. Many of them lose a great deal of these flavors through evaporation and other causes, and this is another frequent cause of spoilage in storage.

The confectioner, like the biscuit maker, depends chiefly on quick handling to overcome his spoilage difficulties, but frequently his efforts are defeated and his goods returned as wormy, sticky, "grained," rancid or "stale." Candies are being packed more and more in metal and glass containers to get around some of the causes of spoilage and, judging from the rapidity of growth, with a great deal of success.

The non-alcoholic beverages are almost always stored in hermetically sealed glass bottles and for this reason cannot be included among the food products preserved by simple storage. Basic syrups from which these beverages are made are frequently stored in barrels and tanks and should be included. The syrups so stored are subject to infection by yeasts and molds and to losses

by evaporation, leakage and certain chemical changes. Infection by micro-organisms is best controlled by attention to the composition of the syrup and by proper sanitary precautions. Other spoilages cannot always be prevented but may be mitigated by attention to the tightness of the container, time and temperature of storage, etc.

Storage or "ageing" is an essential part of the process of manufacture of distilled liquors. The time of storage varies from a few weeks in the case of beer, ale, etc., to several years for wines and spirits. The ageing process causes desirable flavor changes and adds greatly to the value of the beverage.

Alcoholic liquors are stored in glass bottles, stoneware vessels, and wooden barrels and hogsheads. Glass-lined steel tanks have also been used to a considerable degree in breweries. The containers for fermented liquors may be practically hermetically sealed but the general custom is to age spirituous liquors in wooden containers which allow oxygen to diffuse into the liquor. Oxidation by this diffused oxygen plays an important part in the flavor changes that take place in distilled liquors. Water and alcohol also diffuse out through the wooden containers and therefore a considerable volume of the spirits is lost during ageing. This, however, is about the only possibility of loss, the high alcoholic content of the spirits making them immune against practically every other cause of spoilage.

Stored fermented liquors are not so free from trouble. With wines and beers there is always the possibility of a secondary fermentation which may cause great damage.

It is worthy of note that the basic discoveries of bacteriology were made by Pasteur while he was working on the so-called "diseases" of beer and wines. Heating to a temperature of from 140 to 150° F.—"Pasteurization" was the remedy discovered and later applied to milk and other foods.

CHAPTER VIII

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED)—REFRIGERATION

Effectiveness Against Causes of Spoilage—Application of Cold Storage to Cereal Foods—Legumes—Nuts—"Vegetables"—Fruits—Fungi—Flesh Foods—Milk and Dairy Products—Eggs—Edible Oils and Fats—Refined Carbohydrates—Baking Products—Confectionery—Non-alcoholic Beverages—Distilled and Fermented Liquors.

We have already noted the fact that temperature of storage has a profound effect on practically every cause of food spoilage. In general, the lower the temperature of storage, the better most food products keep. These facts have been known and taken advantage of for centuries by the inhabitants of the temperate and frigid zones who use the natural cold of winter for preserving the meat of animals killed in the chase. Natural cold is still used to a limited extent for food preservation by farmers and in small communities, but the uncertainty of the weather in most countries makes the risk of spoilage very great. The invention and development of artificial refrigeration which makes it possible to control temperatures of storage exactly in all weather and in all seasons has revolutionized methods of food preservation and distribution and as a result has had a very great influence on the development of our whole social system.

Artificial refrigeration or "cold storage" is probably the most generally applicable and, with the exception of general warehouse storage, the simplest of food preservation methods. Almost any food in any kind of container may be put into cold storage with reasonable certainty that it will be kept from spoilage longer than in ordinary storage. When we examine in detail the effect of reduced temperature on each agency of spoilage, the reasons for the efficiency of cold storage are apparent.

Cold storage is not an entirely efficient protection against the destruction of foods by rats and mice. Cold storage warehouses, however, are usually so well inspected and protected by the usual precautions against animal pests that damage is not very frequent.

Artificial refrigeration is highly effective against all insect pests as long as the product remains at the reduced temperature. Many insects may remain dormant during the storage period in either the adult, larva or egg stage and develop later within a few days after removal from storage. No insect pests which infest foods can breed and develop at the temperatures used in cold storage, however, and this means is therefore one of the most commonly used protective methods.

Bacteria, yeasts and molds are almost entirely prevented from growing by cold storage temperatures. A very few species are able to develop at comparatively low temperatures but near the freezing point of water even these cease to multiply. Micro-organisms can do but little damage to foods unless they are able to develop and multiply freely. Foods in cold storage are therefore safe as long as the storage temperature remains low. Low

temperatures, however, do not as a rule kill the micro-organisms and they are usually present and ready to develop in foods in which they are able to grow as soon as the temperature becomes favorable.

Most of the enzymes, whether natural constituents of the foods or secretions of micro-organisms infesting them, are practically dormant at cold storage temperatures. Enzymes usually have a narrow range of temperatures at which they function with maximum activity. This optimum temperature is always within the range of temperatures in which the living organism which secretes the enzyme grows best. Enzymes in flesh foods are most active near the body temperature of the animal of origin. Enzymes from plants and micro-organisms reach greatest activity within the range of temperatures where their source flourishes best. None of these temperatures embrace the cold storage range and it is therefore obvious that enzyme action will take place very little, if at all, under refrigeration.

Cold storage has a great deal of beneficial influence over most cases of chemical and physical decomposition. The rapidity of oxidation, a strictly chemical change, is greatly reduced at low temperatures. Colloidal reactions are slowed up in some cases but in others may be accelerated. Products susceptible to crystallization difficulties, such as syrups, candies, etc., are likely to have these troubles increased in cold storage, because of the fact that the solubility of most substances decreases with lower temperatures with a resulting increase in the tendency to crystallize.

Products that are injured by humid air should not be

put in cold storage without the protection of hermetically-sealed containers. Cold storage air is almost invariably of high relative humidity and this condition causes susceptible products to absorb water with consequent spoilage when brought back to normal temperatures.

Since cold storage conditions favor spoilage by humid air, it is but natural to find that spoilage due to evaporation is greatly reduced. The tendency of water and other volatile substances to evaporate is greatly reduced by low temperatures. This, combined with the fact that cold storage air contains almost all the water that it is capable of holding, limits evaporation spoilage to a minimum.

Application of Cold Storage

Cereal Foods.—The cereal grains in bulk are seldom stored under mechanical refrigeration. Grain is sold at such low prices in comparison with other foods and is handled in such large volume that it is cheaper to combat its natural enemies with poisons and fumigants than to use the more certain, but more awkward and expensive, cold storage. Sometimes processed cereal foods, such as rolled oats, cake flours, etc., are temporarily put in cold storage to ward off the attack of insects. Some cereal products absorb too much water in cold storage and lose crispness and other desirable attributes. This, however, is the only risk, as cold storage is very efficient protection against the enemies of all kinds of stored cereals.

Legumes.—In general the dried legumes possess the

same keeping qualities as the cereals and are handled similarly. Fresh legumes in cold storage will be discussed under "vegetables."

Nuts.—Cold storage is the most universally used method for preserving nuts in bulk. Practically all shelled nuts are put in cold storage whenever they have to be kept for longer than a few days. The commoner causes of spoilage in nuts, insect infestation, molds and oxidation rancidity, are all well controlled by reducing the temperature of storage and in most cases, none of the other causes of spoilage give enough trouble to warrant taking special precautions against them.

Vegetables.—While cold storage cannot be relied upon to keep fresh vegetables for long periods of time, it is becoming of increasing importance in this field. By means of refrigerated cars and ships we are able, in the larger cities, to enjoy many fresh vegetables the year around. While low temperatures prevent the development of most causes of spoilage, there are certain micro-organisms which are able to grow in the more watery vegetables at low temperatures. In addition to this cause of spoilage, there are certain life processes that continue after the vegetables have been gathered, rapidly at ordinary temperatures but more slowly at the temperature of cold storage. These life processes may result in the vegetable becoming soft and unmarketable. Softening may give the micro-organisms a chance to start development and still further hasten spoilage. Refrigeration is therefore used chiefly as a means to allay spoilage until the fresh vegetables can be safely transported to market. For this purpose it is comparatively effective

and has made it possible to ship fresh vegetables hundreds and even thousands of miles from producer to consumer.

Dried vegetables act in cold storage very much like the cereals, legumes and nuts. Their principal enemies are insects and molds and these of course are held in check by refrigeration. There always remains the possibility of absorbing moisture, however, and this must be guarded against.

Canned vegetables may be kept in cold storage to minimize objectionable chemical reactions such as absorption of tin from the can, color changes, etc. This is seldom done but would probably be more often resorted to if the beneficial results were more generally known.

Fruits.—The behavior of fruits in cold storage is very much the same as that of vegetables. While all fruits may be kept better at low temperatures than at the temperature of ordinary storage, there are certain microscopic organisms which hasten spoilage at comparatively low temperatures. As with vegetables, fruits continue to undergo ripening processes of an enzymic nature which proceed slowly even at very low temperatures. For this reason fresh fruits cannot be kept in cold storage for long periods as can many other foods. Though none of the fruits can be kept for long periods in cold storage, some varieties keep a great deal better than others. Berries can only be kept for a few days, unless previously crushed and sugared. Apples on the other hand if well selected and packed may be kept for several months. Other fruits occupy an intermediate position, storage of from one to eight months being the usual period.

On account of their high sugar content, most dried fruits tend to absorb moisture if put under artificial refrigeration. This is not ordinarily a serious drawback although there is always the possibility that molds will develop if too much water is absorbed. Cold storage, however, is a sure remedy for the worst evil of dried fruits—insect infestation—and therefore is widely used.

Fungi.—The edible fungi—yeasts and mushrooms—are probably the most perishable of food stuffs and their life in cold storage is limited to a few days. This few days delay, however, has made it possible to build up an enormous industry for supplying yeast to the baking trade and to the home. The marketing of mushrooms is also made possible by the proper application of cold storage.

Animal Foods

Flesh Foods.—In the marketing of flesh foods we find cold storage developed to its highest state of usefulness. From the time that the animal is killed until its flesh reaches the table of the consumer, it is under the influence of artificial refrigeration. The equipment for producing the cold atmosphere for storage may vary from the refrigerating plant using thousands of horse power to the kitchen ice box, but all are effective and necessary in the chain of delivery from the packing house to the home.

The principal causes of spoilage with which the meat dealer and packer has to contend are insect pests, bacteria and enzyme action. Properly applied refrigeration is almost a positive preventive of all these spoilages and therefore is almost the ideal method of preservation

for meats. The principal insect enemies of flesh foods are several species of flies which lay their eggs in fresh meats under favorable temperature conditions. Within a few days these eggs develop into larvæ or maggots, making the food utterly unfit for consumption. At the ordinary temperature of cold storage all these flies become dormant and of course cannot deposit eggs or carry on any other activity.

The class of micro-organisms which cause the most trouble in flesh foods are the putrefying bacteria. These bacteria make themselves evident in a few hours at summer temperatures by causing softening of the flesh and the evolution of evil-smelling gases. Some of the putrefying organisms develop toxic substances which cause illness and even death, if foods are eaten in which they are actively growing. Cold storage prevents the development of these and practically all other micro-organisms if properly applied.

As we have learned in a previous chapter, all fresh flesh contains active catalytic substances called enzymes which have the power to initiate many desirable as well as undesirable changes. Although enzyme changes in stored foods are not all thoroughly catalogued, the laws governing their general behavior under various conditions are quite well known. It is a thoroughly established fact that enzyme activity decreases rapidly with a decrease in temperature and at cold storage temperature almost ceases.

Meats which are cured with salt, or by smoking and other chemical preserving processes, also benefit by being kept at reduced temperatures. In spite of the

preservative effect of these processes, some of the enemies of stored meats are able to gain a foothold in the course of time. Cured meats which ordinarily could not be kept with safety for more than a few weeks at ordinary temperatures, may be kept for a year or more under proper cold storage conditions. In addition to controlling insect and bacterial pests and enzyme changes, cold storage helps to reduce the effect of the slow chemical changes which become evident after several weeks storage. Rancidity of the fat is the commonest of these changes.

Cold storage may be used to prevent undesirable chemical changes in canned flesh foods but is seldom necessary unless the product is to be stored for a long period. Blackening of the inside of the can caused by the development of sulphurous gases may be at least partly controlled by cold storage. Rusting of the outside of the tin due to dampness must always be anticipated.

Dairy Products.—Artificial refrigeration is of tremendous importance in the production and marketing of dairy products. By efficient cooling arrangements from the dairy farm to the consumer, it has become possible for the dweller in large cities to receive pure milk from farms hundred of miles away. As milk is an essential food for children, the importance to public health is obvious.

Milk and cream are watery foods, very sensitive to bacterial and enzyme spoilages. Cold storage cannot prevent these agencies from affecting milk for more than a few days but these few days are sufficient to give time for marketing and distribution. In controlling bacterial

spoilage, refrigeration is assisted by cleanliness and sanitation all along the lines of distribution. It must be understood that cold retards but does not entirely stop the spoilage of milk and that the rate of spoilage depends largely on the number of bacteria that are allowed to get into the milk through dirty pails, dust from the air, falling dirt and other causes. It is not practical to keep raw milk sterile but the number of bacteria can be kept to a minimum by careful handling and immediate cooling.

Pasteurization or partial sterilization by heat, is often used to assist preservation by artificial cooling. This subject will be taken up in detail later.

Butter, the next most important dairy product, is equally benefited by cold storage. By increasing the length of time for which it can be stored and the ease with which it can be safely transported for long distances, refrigeration has stabilized to a great degree the world market for butter.

Butter, in composition, consists principally of butter fat and contains emulsified therein, in the form of small globules, a watery fluid comprising casein, milk sugar and a small amount of milk mineral salts. Salt is usually added as a condiment and preservative. Since its water content is comparatively low and since the water globules are surrounded by a fatty envelope, butter presents quite a different preservation problem from milk. Bacteria and enzymes are not able to exert such a marked influence but oxidation and other chemical and physical changes come strongly into play. Because of its composition, butter can be held at very low temperatures if desired, and this combined with the fact that its causes

of spoilage are readily controlled by low temperatures makes it possible to keep it in first class condition for several months. As with milk and foods in general, the keeping qualities of butter depend largely on the soundness and cleanliness of the materials from which it is made and the care with which it is handled after making.

Cheese.—Many kinds of cheese keep fairly well in ordinary storage. Others must be kept at reduced temperatures if held for more than a few days. If cheese of any kind is to be kept for long periods, however, cold, storage is the logical method of perservation to be used.

Cheese in general is produced by the action of various forms of micro-organisms on the solid constituents of milk. The characteristics of cheese are controlled by the kind of milk, the methods of treating the milk, the addition of other ingredients such as salt, the temperature and time of curing, and other considerations. After the manufacturing process is complete there is a tendency for the product to continue to change by reason of the presence of the living micro-organisms and the enzymes which they evolve. The growth of micro-organisms and the activity of enzymes are brought almost to a standstill under efficient cold storage conditions and it is mainly for this reason that artificial refrigeration is so useful in preserving the numerous commercial varieties of cheese.

Dry Milk.—Milk that is dried to a powder becomes free from danger of spoilage by micro-organisms. The fine state of division, however, makes the conditions for oxidation and rancidity of the fat almost ideal. Storage under artificial refrigeration is effective in reducing the

rate of development of this condition and is often used when the product is to be held for several months.

Eggs.—The preservation of eggs in the shell by means of artificial refrigeration has become an enormous business. Cold storage has made it possible to transport eggs from the places where conditions for production are most favorable and to store them until demanded by the consumer. A service of incalculable worth is thus rendered both to the producers and the consumers with intermediate profits for the agencies of transportation and distribution.

The shell of the egg is a fairly effective means of preservation in itself. It forestalls the attacks of insects and, as long as it remains dry, is proof against all forms of micro-organic life. However, it consists of porous calcium carbonate and a membrance which is permeable by water and therefore it allows the egg to dry out gradually. It must be remembered also that an egg contains the germ of life and is intended to form the embryo fowl and nourish it until hatched. It follows, therefore, that all eggs contain potentially active enzymes and that under proper temperature conditions these enzymes will affect the flavor and other characteristics of the egg. Cold storage owes its efficiency in preserving eggs to the fact that it holds these enzyme changes in check and at the same time reduces the tendency of the water in the egg to evaporate through the shell.

Frozen Eggs.—The preservation of eggs which have been removed from the shell presents some entirely different problems. As soon as the shell of the egg is broken, the first line of defense against bacteria, yeasts

and molds is removed. Since the white and yolk of the egg both contain plenty of water and all the essential food elements for the growth of most micro-organisms, a certain number of spoilage micro-organisms are sure to get into the eggs as soon as broken. For these reasons, steps to reduce the temperature of the broken eggs must be immediate and severe. In practice the eggs are opened into cups and examined for spoilage. If found to be fresh, they are put into a larger container and then poured into a cooling and mixing vat where the temperature is reduced to about forty degrees Fahrenheit. The cooled eggs are then put into the final containers, usually tin cans, and frozen solid. In this condition they may be kept for a year or even more without great deterioration. The number of living micro-organisms in frozen eggs actually decreased during storage, although there are always plenty of them left to start spoilage after the eggs are thawed. Enzyme activity is also stopped but certain chemical changes go on slowly. These changes make themselves evident by the bleaching of the yellow color of the egg yolk wherever exposed to the air. The progress of the oxidation is so slow, however, that its effects are not noticeable until after several months of storage.

Dried Eggs.—Dried eggs are comparable to dried milk in keeping qualities. Cold storage is of considerable benefit although extremely low temperatures are not required. The principal causes of spoilage of dried eggs are chemical in nature and reduced temperatures are very effective in controlling them.

Refined and Manufactured Foods

Edible Oils and Fats.—The principal causes of spoilage of edible oils and fats are chemical in nature and for this reason artificial refrigeration is very effective in preserving them. It may be stated as a general rule that all edible fats and oils are benefited by cold storage, though many of them deteriorate so slowly under ordinary storage that spoilage is not evident for several months.

Oil that is stored in large containers keeps better than if stored in barrels or smaller vessels. This is for the reason that the larger tank presents a small surface to the air in proportion to the volume of oil.

Refined Carbohydrates.—The dry sugars and starches are so free from spoilage of all kinds that cold storage is never necessary. Raw sugar or moist carbohydrates of any kind may be preserved for as long as desired, but these substances are so cheap that the expense of cold storage is prohibitive in most cases. Syrups may be preserved in cold storage during particularly warm and humid weather. If the syrups are properly made, however, this is seldom necessary.

Bakery Products.—Very few bakery products can stand the atmospheric conditions of cold storage unless in hermetically sealed containers. Most bakery products are delivered to the consumer within a very few days and the spoilage agencies which cold storage is so effective in controlling do not have time to develop. Crackers, biscuits and other crisp products rapidly become soft and flabby in the humid air of ordinary cold storage. But for this, cold storage would be an effective

means of controlling rancidity which is one of the most serious troubles of the cracker and biscuit baker.

Confectionery.—Few finished confectionery products can be stored to advantage under artificial refrigeration, though many of the raw materials used by confectioners are so stored as a matter of necessity. Finished candies, as a rule, are subject to damage from moist air. Chocolates are liable to spoilage by condensed water, or "sweating," when removed from storage into hot, moist air.

Non-alcoholic Beverages.—Carbonated non-alcoholic beverages do not require cold storage as a method of preservation, although they are always artificially cooled before consumption. Syrups and other constituents of soda fountain drinks are frequently put in cold storage as a matter of precaution, although the sugar content of the syrups is usually sufficient for preservation.

Distilled and Fermented Liquors.—Cold storage is never used for keeping distilled liquors. Fermented liquors, however, are frequently kept in artificially cooled rooms, though extreme cold is not necessary. Fermentation and ageing of beer, ale and wine are best controlled by a close watch on temperature conditions. Wine fermentation and ageing temperatures are usually controlled by storage in naturally cooled cellars and caves. Breweries are provided with the highest type of refrigerating machinery.

CHAPTER IX

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED)—DEHYDRATION

Effectiveness Against Causes of Spoilage—Application of Dehydration to Cereal Foods—Legumes—Nuts—"Vegetables"—Fruits—Fungi—Flesh Foods—Dairy Products—Eggs—Sugar and Starches—Edible Oils and Fats—Bakery Products—Confectionery—Alcoholic and Non-alcoholic Beverages.

We have already learned of the profound influence that water exerts on almost all forms of food spoilage. Since the presence of large amounts of water in foods greatly increases the probability of spoilage it follows that the removal of excessive amounts of water from foods will exert a corresponding decrease.

This rule is generally applicable to all classes of foods but, of course, the water must be removed in such a way that the highest possible food value of the products is preserved. Removal of water from foods for purposes of preservation has been practiced by natural means for untold centuries and these natural methods are used today, almost unchanged, to a greater extent than ever. Modern methods of artificial drying have also been brought into wide use so that dehydration must be given rank as one of the most important of food preservation methods.

The effectiveness of dehydration may be judged by

noting briefly its influence on the common causes of spoilage.

Animal Pests.—Dehydration of foods is no protection against the depredations of animal pests. All animals require water to aid their digestive processes but have the ability to get their supply of water from one source and their nutriment from another.

Insect Life.—Removal of water from foods is a help rather than a hindrance to insects in that it saves the food from spoilage from other causes and gives the insects a better chance to develop. All dried foods that are stored for long periods of time must therefore be specially guarded against insect infestation.

Micro-organisms.—Dehydration, if properly carried out is a specific remedy for all damage by micro-organisms. Some molds have the ability to grow on foods that are only slightly moist and therefore the greatest care must be taken that all dehydrated foods are thoroughly dried and that, after drying, they are kept dried by proper protective means. Bacteria and yeast vary with respect to the amount of water required for their development but as a general rule their growth is arrested considerably before complete dehydration is accomplished.

Enzyme Action.—Enzyme action is completely arrested by dehydration. If the dehydration is carried on at low temperatures, however, the enzymes remain dormant until they are again brought in contact with water with other conditions favorable for their activity.

Chemical and Physical Decomposition.—There is no uniformity in the effect of dehydration on the several

forms of Chemical and Physical food spoilage. Dehydrated foods are particularly prone to suffer from oxidation for the reason that other more rapid forms of spoilage are held in check by the removal of water.

Dehydration of foods results in marked colloidal changes in the structure of most foods. In fact one of the severest criticisms to which dried foods may be subjected is that the natural cell structure is changed and that, therefore, they do not come back to their original state when "freshened" with water. The advantages of dehydration are so great, however, that such criticisms are hardly justifiable.

Application of Dehydration

Cereal Foods.—In cereals we have an example of the use of dehydration by nature. In fact nature equips most seed producing plants with a very efficient dehydrating plant by which the seed is protected from spoilage until time for germination and reproduction. In growing and harvesting the cereal grains and other seeds, man merely takes advantage of this provision of nature and simply collects the ripe grain after it has become sufficiently dry to handle safely.

Legumes.—The matured legumes are dry seeds and fall into the class of naturally dehydrated foods with the cereals. So efficient is this natural dehydration that these products must only be protected from animal and insect pests and the weather, to keep indefinitely.

Nuts.—Nuts may also be included in the class of naturally dehydrated foods although the natural method is not as reliable as when artificial means are resorted to.

Most nuts, when harvested, are very moist and unless dried out in thin layers, within a reasonable time, micro-organisms gain entrance and cause rancidity and other forms of spoilage. Practically all nuts which spoil in the shell do so from this cause.

The coconut must be considered as an exception to the above. Its hollow interior, partly filled with a watery fluid, makes it entirely different from any other nut. For efficient preservation, man has learned to remove the shell and finely divide the kernel so that artificial dehydration may be efficiently applied. As a result of this process, dessicated or dehydrated coconut has become a staple article of commerce all over the civilized world.

Vegetables.—Considered superficially, vegetables appear to offer a very great field for the practice of dehydration. Since vegetables contain from seventy-five to ninety-five percent of water which can be almost entirely removed, the possible saving in freight and storage space is very large. Dehydrated vegetables however, have not come into general use for a number of reasons. Most vegetables cannot be dried in the haphazard way in which the more commonly used food articles are handled. They require the careful control of the drying conditions that can only be obtained by a skilled manufacturing organization under scientific supervision. Such organizations are rare and the few that do exist are not powerful enough financially to educate the public in the use of their products.

Another obstacle to the general use of dehydrated vegetables in the home is the failure of the industry in

general to face the fact squarely that their products will not keep indefinitely under any condition of storage, but on the contrary, are semi-perishable products, subject to insect damage, the growth of certain micro-organisms and several forms of physical and chemical spoilage. Of course, all of these causes of spoilage can be controlled by properly selected auxiliary preserving processes, but there is little hope in the present policy of denying that spoilage occurs.

When the operation is properly carried out almost any vegetable may be dehydrated into a product which can be "freshened" in water by the consumer and brought back into a state closely approximating the original in flavor, appearance and food value. Under present conditions in the industry, dehydrated vegetables of the above description cannot be obtained in the markets of the world. The advantages of dehydrated vegetables, however, are so great that there is no doubt that eventually the problems that now block the way will be solved and the industry gain its rightful place.

Fruits.—Fruits, particularly those rich in sugar, have been dried for centuries. Figs, dates and dried grapes or raisins are mentioned in some of the oldest writings of man. These Old World fruits have been supplemented by prunes, peaches, apricots, apples and others until at present the drying of fruits ranks with the largest of the food industries.

The excellent keeping qualities of dried fruits are due primarily to their natural sugar content. When in concentrated solutions, sugars are extremely efficient preservatives against practically all forms of micro-

organisms. Concentration of the sugar in dehydrated fruits is carried to a very high degree by the evaporation of the water and by this means, danger of spoilage by micro-organisms is almost completely avoided. Dehydrated fruits, however, are subject to insect infestation and to various physical and chemical spoilages, traceable to unfavorable atmospheric conditions. For these reasons, auxiliary methods of preservation must be resorted to if the product is to reach the consumer in a sound and edible condition.

Fungi.—Yeast may be dehydrated and kept from spoilage for comparatively long periods, but the temperature of drying must be very low, if the yeast cells are to remain alive. Yeast extracts, which have gained some usage as food, are usually dried or evaporated to a thick paste which has excellent keeping qualities on account of the lack of water and the high content of natural and added salts.

Mushrooms are preserved by drying quite extensively and their keeping qualities are very good if well taken care of after drying. Dried mushrooms are extremely likely to develop insect contamination and are also very susceptible to atmospheric conditions. For this reason they are not in very good repute as an article of food and therefore are not used very extensively.

Flesh Foods.—Very few flesh foods are dried without previous treatment with salt or some other chemical substance. Certain savages make a practice of drying meat in thin slices, either in the sun or over wood fires, but this may be neglected as being of little commercial importance. Salting and smoking (which will be discussed

in detail under "Chemical Preservation") may be considered as dehydration methods, since water is actually removed from the flesh by both methods, but this dehydration is only incidental to the main end which is chemical preservation. Some varieties of salt-cured fish are deliberately dried, and this may be classed as a true dehydration, for the reason that it is a necessary and important part in the preservation process.

Dehydration of flesh foods, when practiced, is a very efficient method of preservation. It would undoubtedly be used more if other more convenient methods were not available.

Dairy Products.—The drying of milk into a powdered product has grown, of late years, until it bids fair to become an important rival of condensed milk. This dehydrated product has also suffered by the failure of manufacturers to recognize the fact that removal of water was not a positive cure-all for every kind of spoilage. These manufacturers did not remain very long in ignorance, but by persistent experiment found that cold storage and other auxiliary methods of preservation would carry their product in perfect condition to the consumer. By dehydration, eighty-five percent of the weight of this extremely perishable product is removed and at the same time, it is converted into a comparatively stable powder. The economic advantages of such a process are obvious, and it is not surprising that the business is growing by leaps and bounds.

Eggs.—The development of dried eggs has almost paralleled that of dried milk. The preservation problems are almost identical in both products, and were solved by

much the same methods. If anything, dried eggs are more stable than dried milk, and for this reason, the dried egg has come into use more rapidly. Since the beginning of the twentieth century, enormous plants for drying eggs have been established in China and the product of these factories is used in almost every commercial bakery. Properly prepared, dried eggs are a fine, wholesome food product and their use cannot be reasonably condemned from any standpoint. If made from sound eggs, the product should reach the consumer free from the appearance and odor of spoilage. If the product is not sound, the presumption should be that the original raw materials were not sound in the beginning.

Refined and "Manufactured" Foods

Sugars and Starches.—The sugars and starches may be taken as examples of what dehydration is capable of doing when the dehydrated product is not susceptible to spoilages that go on in the absence of water. While these substances are not dehydrated in the ordinary meaning of the word they are examples of true dehydration, in that practically all water is removed during the refining processes to which they are submitted. Since they are not subject to the inroads of insect pests, nor affected by physical or chemical causes of spoilage in the absence of water, they remain in the same condition indefinitely when thoroughly dried.

Edible Oils and Fats.—The edible oils may also be considered as dehydrated foods, being practically water free, but they differ in keeping qualities from the sugars and starches by being very susceptible to the chemical

action of the oxygen of the air. This action results in rancidity, the bug-bear of the edible oil industry. Chemical oxidation is practically the only form of spoilage likely to damage well prepared edible oils, as freedom from water is enough, in this case, to insure safety from insects and the action of micro-organisms.

Bakery Products.—The process of baking is in reality a dehydrating process and the keeping qualities of bakery products are due largely to the removal of water. Bread and cake are not sufficiently dehydrated during baking to become immune to the action of molds but the biscuit and cracker baker must rely on dehydration during baking for his protection against micro-organisms and most other spoilages except oxidation rancidity.

Confectionery.—Most confections are made by a boiling or evaporation process that results in dehydration. The fact that candies contain little water frees them from all danger of spoilage by micro-organisms. Toward other causes of spoilage the behavior of candies is governed largely by their composition, some being very sensitive to humidity, others, containing butter, to oxidation rancidity, etc.

Beverages.—It would seem rather far-fetched to speak of dehydrated beverages since water is an essential constituent of all beverages. Upon investigation, however, we find quite an industry based upon the preparation of more or less water free substances which are later to be dissolved or diluted with water for beverage purposes. We have already discussed dried milk, one of the most important of these products. Liquid and solid coffee extracts may also be mentioned. Syrups for soda foun-

tain and other similar uses may be classed as dehydrated beverages, since they are made water free largely for preserving purposes.

Alcoholic beverages may not be treated in this way, for the rather obvious reason that the most valued constituent, the alcohol, may be depended upon to vaporize first in almost any dehydration process.

CHAPTER X

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED) — CHEMICAL PRESERVATION

Definition of Chemical Preservation—Classification of Chemical Preservatives—Harmless Preservatives (Class I)—Sugars—Salt—Vinegar—Wood-Smoke—Carbonic Acid Gas—Spices—Antiseptic Chemical Preservatives (Class II)—Potassium Nitrate—Sulphur Dioxide—Benzoic and Salicylic Acids—Formaldehyde—Boric Acid—Miscellaneous Preservatives.

At the mention of "chemical preservation," we think first of the rather notorious chemicals such as benzoate of soda, formaldehyde and borax. While these chemicals have had more or less extensive usage, they are all of minor importance when compared with such substances as sugar, salt and vinegar.

We have become so accustomed to the use of sugar and salt as constituents of our diet that we do not consider them as chemical preservatives. Nevertheless, their preservative action is purely chemical in nature and therefore we must consider them along with formaldehyde, sulphur dioxide, borax and other substances in more or less bad repute among health authorities.

Chemical preservatives are added to foods for the purpose of making them unavailable for use by micro-organisms, insect pests, and even higher forms of life,

without rendering them unfit for use as food for man. As would be expected, this is difficult of accomplishment and the number of chemical substances that can be used, with safety to the food and the consumer, is extremely limited.

The chemical food preservatives fall quite naturally into two classes. The first class comprises those preservatives which are conceded by everyone to be harmless, if not actually beneficial constituents of the diet. Sugar, salt, vinegar, certain organic acids and wood smoke are the most important members of this class. The second class includes formaldehyde, borax, benzoate of soda, potassium nitrate (saltpeter) salicylic acid and other chemical substances known principally for their antiseptic properties. Chemicals of this class are fast becoming obsolete as preservatives, and food laws governing their use are becoming more and more strict. Influenced by public opinion manufacturers of foods have made great efforts to avoid the use of questionable preservatives and in most cases have found much more dependable and safe means of preservation.

Chemical preservatives, whether of the first or second class, vary so widely in composition and in their effect on the food that it is necessary to take them up, one by one, and note their preservative effects on the several classes of foods and the extent of their use.

Harmless Preservatives (Class I)

Sugars.—The sugars are of such great importance, from the standpoint of food value that we seldom consider them in the light of their great usefulness as pre-

servative substances. Sugar is so generally used for bringing out and improving the flavor of foods and in adding to the calorific and energy producing value that we seldom realize that many of our most valued food substances would spoil without it. Sugar used in small quantities is seldom of value as a preservative. If water is present in a food, in any considerable amount, the sugar must be added in very large quantities if preservation is to be accomplished. Few, if any, spoilage bacteria can develop in sugar solutions exceeding forty or fifty percent in strength although certain yeasts and molds are able to develop even when the water reaches the saturation point. On account of its ability to prevent the growth of the difficultly killed spore forming bacteria, sugar preservation is extensively used in conjunction with other methods. These combination methods will be discussed in a later chapter.

All sugars have preservative properties when used in sufficient quantities. The more soluble ones are the more efficient in this respect, although cane sugar, which has a comparatively low solubility, is the most generally used. This difference may be readily demonstrated by preparing "crystallized" or candied fruits with cane sugar and with "invert sugar" which is a mixture of dextrose and laevulose, made by heating a solution of cane sugar with dilute acids. The fruit candied with pure sugar will be found to be subject to the attack of molds while that made with invert sugar will be free from such contamination. This seems to be due entirely to the fact that a saturated solution of sucrose contains much more water than a saturated solution of invert

sugar. Another illustration of this is the difference in keeping qualities between maple syrup, a sucrose solution and honey, which consists essentially of a solution of invert sugar. The maple syrup is subject to mold and yeast spoilage which never affect honey in the slightest degree. If water is added to the honey until its density is reduced to that of maple syrup, it then becomes susceptible to the same kinds of spoilage.

If the matter of preservation from spoilage only is considered, sugars might be used to preserve almost any food, whether of plant or animal origin. From a practical standpoint, however, we must consider the matter of taste and flavor combinations and other aesthetic considerations. For instance, while it is feasible to preserve meats or fish with sugars, the very thought of so doing is repulsive to most people. It should also be remembered that the principal uses of sugars in foods are for flavor and energy value rather than for the purpose of preservation.

Sugars are seldom used with cereals and legumes for purely preservative purposes. The same may be said for nuts, although sugar may be classed as a preservative when used to coat "glacé" nuts or when the nut meats are impregnated with strong sugar solution and then dried. In these cases, the preservative effect is obtained by the action of the sugar in mechanically sealing the oil of the nut away from the oxygen of the air, which otherwise would produce oxidation rancidity.

Sugars, particularly cane sugar, are used to a great extent in preparing green vegetables for the table, but merely as a flavoring agent. The quantity used is seldom

large enough to have any considerable bearing on their keeping qualities.

It is in the fruit class of foods that the art of sugar preservation reaches its highest development and most extensive application. The sweet taste of the sugars combines perfectly with all fruit flavors, and therefore large, and consequently effective, amounts of them can be used to advantage. The effect of the sugars is to prevent all bacterial development and to restrain greatly the growth of yeasts and molds. These latter organisms are easily killed by comparatively low heating. Therefore fruits heavily treated with sugars and heated enough to kill yeasts and molds may be kept almost indefinitely in vessels sealed tight enough to prevent access of insects and foreign matter. This is a favorite preservation method of millions of housewives, as well as the basis for a great industry in the manufacture of jams, jellies, preserved, candied and glacé fruits, etc. Sugar preservation is also used to very good effect combined with refrigeration in the preparation of berries and other fruits for the ice-cream and "soda fountain" supply industry. In this combination method the fruit is first mixed with a suitable amount of sugar and then stored at a temperature low enough to prevent the development of yeasts and molds. In addition to preventing the growth of micro-organisms, the sugar also serves to retard evaporation and to minimize the formation of ice crystals, which would tend to make the finished ice-cream lumpy.

In the realm of animal foods, sugars do not find much application as preservatives. As mentioned before, the

idea of combining sugars directly with flesh foods is actually repulsive to many. In certain meat curing processes, however, sugar finds limited application in combination with salt and other chemical preservatives. This is primarily a flavoring use and the extent of the preservation effect is problematical.

In the preservation of milk, cane sugar finds a very extensive application. Sugar preserved milk is the familiar "condensed milk" of commerce. The method used in preparing condensed milk is very similar to fruit preserving with sugar. After the milk has been concentrated by evaporation, the sugar is added and the product filled into containers while hot. The sugar prevents the growth of all bacteria which may remain alive, while the yeasts and molds are killed by the heat treatment.

"Evaporated milk," which is identical with "condensed milk" with the exception of the addition of cane sugar, presents an entirely different preservation problem for the reason that the bacteria, not having sugar to prevent their development, must be killed by drastic heat sterilization.

Sugar preservation needs to be considered very little in relation to the "refined" and "manufactured" classes of foods. Purified carbohydrates and edible oils can be eliminated without discussion. The sugars which are used in the baking and confectionery industries are added for their food value and taste rather than their preservative properties. It is probably true that sugar acts as a preservative by mechanically protecting the fatty constituents of some baking and confectionery products from oxidation rancidity.

Beverages cannot depend entirely on sugars for pres-

ervation for the reason that sugar enough for complete preservation would make a beverage undrinkable. Syrups for use in making non-alcoholic beverages, and for other uses also, are essentially flavored sugar solutions of sufficient concentration to insure preservation. When diluted to potable concentration, however, the sugar cannot longer be depended upon, and unless other methods of preservation are used, fermentation by yeasts or molds will almost certainly set in. Alcoholic beverages, both fermented and distilled, contain varying proportions of sugars, but in no case can these be considered as preservations. Usually the alcoholic content is ample for preservation purposes. Carbon dioxide gas and low temperature heat treatments are used as auxiliary means when the amount of alcohol in the beverage is not sufficient for preservation.

It will be noted that in most of the instances of sugar preservation given, the effect of the sugar has been to prevent or restrain the growth of micro-organisms only. When foods are subject to other forms of spoilage, which is generally the case, other properly selected methods of protection are demanded.

Salt.—The efficiency of salt as a chemical food preservative is attested by centuries of use and the fact that today it is more extensively used than ever. Salt is a true chemical food preservative in that it functions to make the food in which it is used unsuited for the growth of spoilage micro-organisms without destroying its usefulness as human food. Salt is also effective against animal and insect pests, although the larva of certain flies often develop in home-cured salt meats.

In judging the effectiveness of salt as a preservative against micro-organisms it is necessary to consider only the ratio of the amount of salt used to the amount of water contained in the food. In other words, the amount of salt that is in solution in the watery juices of the food is a measure of the effectiveness of preservation. Even in minute amounts, salt has a marked influence over the growth of bacteria, yeasts and molds. When the amount reaches a concentration of five per cent in the watery portion of the food, the development of most of these micro-organisms will have ceased. From eight per cent to saturation (about 25 per cent) are the amounts commonly used in practice. Often salt is added to foods in much greater amounts than can be absorbed by the liquids. This remains in the form of crystals but does not assist in preserving the food after its juices have become saturated.

As in the case of sugar, we find that salt is universally applicable as a preservative but that it is restricted practically to foods with which it can be combined without offending the organs of taste and smell. It must, like all preservative methods, compete with all other methods and show superiority in order to be selected. For these reasons salt finds little use in the perservation of cereals and legumes. We find salt used to a certain extent in the marketing of nut meats but it is added primarily as a condiment. In fact, in most cases salt is an actual detriment to the keeping qualities of nuts on account of its tendency to absorb water from the air.

Preservation in salt brine is a standard method of treating vegetables, especially those destined to be

used in pickles. The vegetable to be preserved is simply kept immersed in a brine of suitable strength, and may be kept thus for a time varying from a few weeks to a year or more, depending on the strength of the brine and the temperature of storage. Almost any "vegetable" may be kept in this way, but the brining method of preservation is largely confined to cucumbers, green tomatoes, cabbage, cauliflower and other pickle and "relish" constituents.

The idea of putting fruits in brine is almost as repulsive to our minds as that of adding sugar to meats. Still we find salt used to a considerable extent in the preservation of fruits, though few reach the ultimate consumer in that form. A brined fruit which is familiar to everyone is the ordinary green olive which is preserved, after preliminary treatment with other chemicals, in a salt solution of from seven to ten per cent strength. This method is very effective as long as air is kept away. Oxygen, coming in contact with brined olives, causes a dark discoloration and an astringent taste. This condition is readily remedied by using only air-tight containers.

Large quantities of lemon, orange and citron peel are preserved in brine as a preliminary to a final treatment with sugar. The brined fruit peel is often kept for several months until ready for treatment. Before the sugar is added by boiling processes, the salt is almost entirely washed out with fresh water. Cherries and other fruits used for "candying" or "crystallizing" are treated in the same way, often with the addition of sulphur dioxide to the original brine.

The most important use of salt as a preservative is undoubtedly in the curing of flesh foods. Salt-cured pork, beef and fish is almost a daily article of diet. The salt curing of all flesh foods is extremely simple in principle, the purpose of applying the salt being to saturate the natural water in the meat with salt. The salt molecules have the property of penetrating or diffusing through the flesh, so that thorough permeation is obtained in a short time. The salt may be applied dry to the surface of the fresh meat or fish or by means of a brine or solution. Both methods are extensively used. When the flesh food to be salted contains large amounts of water and is easily compressed, the addition of dry salt often causes a large percentage of water to leave the cells of the flesh and to come to the surface, forming a natural brine without the addition of water.

Though salt-cured meats and fish keep very well if kept at a temperature below 65° F. they are likely to develop spoilage of enzymic and chemical origin if the temperature rises. A few forms of bacteria are also able to exist on strongly salted foods and often cause trouble, particularly with fish.

Salt is widely used as a preservative for butter and cheese. In butter the salt added dissolves in the watery fluid which is emulsified in the solid butter fat. Its presence has a great deal to do with the keeping qualities of butter although salt alone cannot be credited with being a very efficient preservative for butter when compared with refrigeration.

The presence of salt in cheese has a great deal to do with its ripening processes as well as its keeping qualities

afterwards. We cannot judge cheese by other food products since what passes as an excellent flavor in some cheeses would be called rank putrefaction if discovered in meat, eggs or almost any other food. The changes which go on in cheeses will be more fully discussed in the chapter on "Preservation by Fermentation."

Salt is a very efficient preservative for broken eggs but is seldom used for anything but inedible egg-yolks destined for the tannery. Frozen eggs and dehydrated eggs are so firmly entrenched in the baking industry, that salt preservation has not had a chance to break in. This is a field that may be opened in the future if an advantageous use for the product can be developed.

In the field of "manufactured" foods, salt has little application as a preservative. The sugars, starches and edible oils and bakery and confectionery products are all practically water free and hence are not open to the causes of spoilage against which salt is most efficient. It is obviously impracticable to use salt in any form of beverage, the principal object of which is the quenching of thirst.

Looking back for a moment we find that the principal use of salt as a preservative is in those classes of foods which contain comparatively large amounts of water. In these foods salt tends to stop the development of spoilage micro-organisms and insects. Enzyme action and chemical and physical changes may sometimes be influenced favorably by salt preservation, but in most cases these changes must be counteracted by combination with other preservation methods.

Vinegar (Acetic Acid).—Like sugar and salt, vinegar, in the proper proportions, is a universally applicable food

preservative. The active principle of vinegar is acetic acid, an organic acid, principally derived by fermentation from dilute alcoholic solutions such as wines, cider, beer, etc., or simply from pure alcohol diluted with water. Strong acetic acid is also derived from the liquors from wood distillation (wood vinegar), but in this form is seldom used as a food preservative. The fermented vinegars of commerce, the commonest of which are wine, cider, spirit and malt, contain from four to ten per cent of acetic acid. For preservative purposes these vinegars are usually added so that the amount of acetic acid in the finished food is from one-half of one per cent to two and one-half per cent. Between these limits acetic acid has marked preservative properties and foods so preserved are not too acid for direct consumption.

The principal virtue of vinegar as a preservative lies in its ability to prevent the growth of micro-organisms and to arrest enzyme action. It also prevents, to a great extent, the attacks of animal and insect pests, but these agents of spoilage would be held in check by the methods of packing in sealed containers which are followed in the "pickling" industry. Slow chemical reactions may go on and cause considerable damage in "pickled" foods. Oxidation, the worst of this class of spoilage trouble-makers, may be prevented to a great extent by heating the product to expel air, filling the container full and sealing as tightly as possible.

Only one form of micro-organism is likely to cause trouble in vinegar-preserved foods. This is *mycoderma aceti*, the vinegar producing bacterium itself. Being able to exist and multiply on the surface of liquids containing

as much as ten per cent of acetic acid they are naturally not daunted by the comparatively small amount used in foods. They are therefore able to multiply freely upon the surface of almost any food containing vinegar. Infection by this bacterium is quite easily overcome for the reason that it requires a liberal oxygen supply in order to multiply. In a sealed container the oxygen supply is soon exhausted and development of the bacterium ceases before it can cause an objectionable change in the product. A low temperature heating or pasteurization is also effective against this micro-organism.

Vinegar as a preservative is used almost entirely on foods containing large amounts of natural water. This eliminates without discussion, the dried cereals, legumes and nuts.

Practically any food in the "vegetable" class may be preserved with vinegar and this fact is well-taken advantage of by the housewife and the manufacturer on a large scale. In our discussion of salt as a preservative we have noted that great quantities of vegetables are preserved in brine as a preliminary to their preparation for ultimate consumption. The vegetables most commonly pickled include cucumbers, cauliflower, onions, cabbage, peppers, string beans and others.

Fruits are also preserved with vinegar but to a much less extent than vegetables. Most of the pickled fruit is put up by housewives. Some remarkably fine products can be made from fruits by the judicious use of vinegar as a preservative but this field seems neglected by the manufacturer.

While vinegar preservation is a perfectly feasible

method of preserving meats, it has never attained general use. A few comparatively unimportant products, such as "pickled pigs' feet," have attained some favor but the total amount is insignificant when compared with the enormous quantity of meats preserved by other methods. Vinegar has received more extensive application in the preservation of fish, but here, too, the percentage is small. Such products as "Bismarck Herring," "Marinated Herring," "Russian Sardines" and "Soused" Mackerel are examples of vinegar preservation applied to fish.

Vinegar is not used at all in the preservation of dairy products and eggs.

The foods which comprise the bulk of the refined and "manufactured" classes—the carbohydrates, edible oils, bakery products and confectionery—are automatically eliminated as subjects for vinegar preservation. Among the beverages, acetic acid is also out of place. Most wines contain acetic acid in small amounts, but its presence is considered a detriment rather than an advantage.

Vinegar is seen to be a very efficient preservative against micro-organisms and enzyme activity and to have positive preservative qualtities against insect and animal life. When combined with hermetic sealing, vinegar preservation may be depended upon to keep most foods to which it is applicable for as long a period as may be desired.

Wood-Smoke.—The preservation of foods by the smoke from smoldering wood is an art that has been handed down to us through successive generations for centuries. It was probably discovered accidentally by some ancient

savage who noted that meat hung near the roof of a dwelling acquired a pleasant flavor and the quality of keeping well. Afterwards he may have used a separate cave or building so that the effect of the smoke could be intensified. This crude invention has come down to us almost unchanged with but little effort towards improvement.

Smoke from slowly burning wood owes its preserving effect to the presence of several chemical substances and to the partial dehydration which usually accompanies smoking. Some of the chemicals present in wood smoke are acetic acid, acetone, methyl or wood alcohol, formaldehyde and several phenolic compounds usually classed under the term "creosote." All of these chemicals have definite antiseptic properties and, since they collect on the surface of and penetrate into the food treated, go a long way towards preventing the growth of microorganisms. Insect and animal pests are also repelled by smoke compounds on foods if in reasonably large concentration. Enzyme changes are stopped in some instances but may proceed unchecked in others. Experience is the only guide in this respect as science has done little to aid. The common chemical and physical spoilage changes are for the most part unaffected by smoke treatment and must be counteracted by other methods of preservation.

Smoking as a method of food preservation is used upon flesh foods only. Smoking could be used on other foods if preservation only was considered, but, as with many other chemical preservatives, we must consider the question of flavor combination. It is probable that

our organs of taste and smell have learned to tolerate the flavor of smoked meat and fish only after centuries of evolution.

In the preservation of meat and fish, smoking is usually combined with salt curing. Where flavor is to be sacrificed to keeping qualities the salting and smoking are both done very thoroughly. Where the flavor is the chief requisite, the salt and smoke are applied sparingly and, if desired, preservation is prolonged by refrigeration. The processes of smoking used are many and varied. Each nation or even locality has its favorite method of "curing." Many farmhouses are provided with "smoke-houses" in which the winter's meat supply, principally pork, is smoked by a slow fire built on the floor, the meat being previously salted. Packing plants have improved on this style of smoke-house mechanically, but the principles have not been changed since the stone age.

The smoking of fish differs little from the methods used with meats. With fish, however, the preliminary salt treatment is even more important since it helps in the preservation and at the same time makes the fish firmer by drawing out large quantities of water. As with meats, fish are smoked in many ways, each community having its peculiar tastes. As a general rule, smoked fish cannot be depended upon to keep for longer than a few weeks at temperatures higher than seventy degrees Fahrenheit. Above this temperature chemical changes, particularly fat oxidation, are likely to cause trouble even where heavy salting and smoking is practiced.

The choice of woods for fuel for producing suitable smoke is very wide. Practically any hardwood can be

used, and also soft woods free from resins. Beech and hickory are favorite woods in the United States. Coniferous woods cannot be used on account of their content of turpentine and resin. Corn cobs produce a very fine flavored smoke and are favored, where available, on farms.

Carbonic Acid Gas.—Carbonic acid gas or carbon dioxide is seldom thought of as a preservative. Nevertheless, it has marked effectiveness as an antiseptic when under high pressure and is effective against many micro-organisms when used only to displace the air in a container. This latter phase of carbon dioxide preservation will be discussed in the chapter on "Hermetic Sealing."

Carbon dioxide under pressure is used only in the beverage industry. In alcoholic beverages it is generated as a by-product of the yeast fermentation. In some of them, such as "sparkling" wines, beer, etc., part of the gas is retained, chiefly as a flavor accessory.

In bottled non-alcoholic beverages carbon dioxide serves primarily as a preservative. Its flavor improving properties in this field are secondary in importance. The non-alcoholic drinks bottled with carbon dioxide usually contain from five to ten per cent of cane sugar and other substances favorable to the development of micro-organisms. Without carbon dioxide under pressure they could not be kept at all unless heat sterilized.

While used in a comparatively small field carbon dioxide preservation is the basis of a very flourishing industry, particularly in the United States, where carbonated sweet beverages are becoming increasingly popular.

Spices.—A few of the commonly used spices have

marked antiseptic properties. These properties are embodied in the flavoring constituents or essential oils. The oil of cloves is particularly effective as an antiseptic and is used as such, very extensively, in tomato catsup and chili sauce. It is undoubtedly not sufficient of itself to keep the product but when combined with vinegar, salt and sugar it adds greatly to the factor of safety. Cinnamon and cassia oils have been found to be antiseptic to a degree, but much less so than cloves.

Antiseptic Chemical Preservatives (Class II)

The preservatives in this class are all antiseptics which have been found, by experiment, to preserve foods against spoilage by micro-organisms without making them more than slightly injurious to man. Strictly speaking, all the preservatives of this class are poisonous substances if consumed in large amounts. Their use in food has been tolerated only when they are added in amounts so small that they can be taken care of by our organs of elimination. This class of preservatives is becoming more and more regulated by restrictive food laws. It is contended by physicians and health officials that no poisonous chemicals should be used in human food no matter how small the amount for the reason that they disturb digestive processes and burden the waste eliminating organs of the body. Those in favor of preservatives of this class combat this argument with the statement that the preservatives are used in amounts too small to be detrimental and that their use is justified by the fact that they simplify preservation methods and therefore enlarge

and cheapen the food supply. With the increased effectiveness gained by the more desirable methods of preservation this latter argument is losing a great deal of its force and more and more manufacturers are adopting the safer processes.

Though antiseptics are losing caste rapidly as food preservatives it will do no harm to take up briefly the properties of those more commonly used.

Potassium Nitrate.—Potassium nitrate or saltpeter is one of the oldest chemical meat preservatives. It is seldom used as a preservative for any food other than the flesh of animals. It is almost always used in combination with salt. Saltpeter appears in many old meat preservation formulas which have obtained wide circulation among farmers. In packing houses it is used largely as a preservative of "corned beef" and various "wursts" and "sausages."

In addition to its antiseptic properties saltpeter has the property of accentuating the color of red meats. This is probably the main reason for its continued use as a preservative as many other chemicals are more effective antiseptics.

Sulphur Dioxide.—This chemical is known to everyone as the fumes of burning sulphur. It has strong antiseptic properties when added to foods and in the gaseous state is an effective insecticide and fumigant for animal pests. It may be added to foods in the form of a gas or as a water solution as well as in chemical combination as sodium sulphite or bisulphite. The gaseous form may be produced by burning sulphur or purchased as a liquefied gas in steel cylinders. The latter form is more convenient

but more expensive than the former. Sodium sulphite and bisulphite are both well-known chemicals.

The principal use of sulphur dioxide as a preservative is in the manufacture of dried fruits. Here it not only aids in keeping the fruit while drying and after drying but bleaches it as well. The use of sulphur dioxide is so well established in this field that some states which have strict laws against sulphur dioxide in other foods allow it in dried fruits as a necessity. Under present methods and trade customs the use of sulphur dioxide in the production of dried fruits is probably necessary but there is little doubt that its use will gradually decrease as time goes on and better methods are worked out.

Sulphur dioxide is also used in solution in brined fruits as a preservative and bleaching agent. A large amount of the fruit used for "candying" and "glacéing" is first preserved by this method. It also finds application in the bleaching of gelatine but this cannot be classed as a preservative use. It is seldom used in other meat products.

Benzoic and Salicylic Acids.—These chemicals are taken together for the reason that their properties and uses as preservatives are very similar. Salicylic acid was formerly used very extensively but has been largely succeeded by benzoic acid, this acid being considered equally as effective as an antiseptic and less likely to cause disturbance in the human organism. Benzoic acid is one of the few preservatives of this class that is given legal recognition as a harmless preservative. The amount that can be used, however, is limited to one-tenth of one per cent.

Both benzoic and salicylic acids are comparatively ineffective as preservatives unless the foods to which they are added contain considerable quantities of acid. Large amounts of preservatives are used in foods in which they are utterly useless on account of failure to recognize this fact. Fruit products and other foods containing natural or added acids are often kept with these chemicals, especially when other methods of preservation are not applicable or available. Common foods to which benzoates and salicylates are commonly added are tomato catsup and "Chili Sauce," pickles and relishes, fruit juices, "soda-fountain" fruits and syrups and numerous others.

Formaldehyde.—Formaldehyde is probably the most effective antiseptic of all the chemical food preservatives and at the same time the most objectionable from the standpoint of health. It is a chemical compound derived, usually, from the oxidation of wood alcohol and is an exceedingly active poison even in comparatively small amounts. It has very great deodorizing properties, probably for the reason that it is very active chemically and forms non-volatile compounds with the odoriferous substances. The deodorizing effect of formaldehyde on even such a smelly object as a putrid egg is remarkable. Incidentally, formaldehyde will destroy a pleasant odor in food just as quickly as an undesirable one.

Formaldehyde, at one time, acquired extensive use as a milk preservative but is now strictly forbidden as such. In fact formaldehyde now has little use as a preservative except for industrial and other purposes not related to foods.

Boric Acid.—Boric or boracic acid and its sodium salt, borax, are antiseptic substances which have been used a great deal in the past as food preservatives. They are now considered to be quite injurious and their use is, in most countries, forbidden by law.

Boric acid has been used in the preservation of broken eggs, milk and other dairy products, canned fruits and vegetables and many other foods. Its use, however, is gradually decreasing and undoubtedly will soon cease.

Miscellaneous Preservatives.—There are many substances which have been proposed as preservatives but which have had so little use that they do not deserve mention. Others have lead some practical application and should be at least made known. Among these are alcohol, formic acid and beta naphthol. Grain or ethyl alcohol has been quite fully discussed elsewhere in its relation to alcoholic beverages. It is mentioned here because it is used to a very limited extent as a preservative of edible fruits. "Brandied" peaches are probably the best known example.

Formic acid and beta-naphthol have been reported as being used for food preservation purposes. Formic acid may have found application in a similar manner to benzoic acid, though there is little to substantiate this statement. Beta-naphthol is eliminated for most uses because of its faint odor, suggestive of coal tar.

CHAPTER XI

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED)—PRESERVATION BY FERMENTATION

Definition of Fermentation Preservation—Preservation by "Lactic" Acid Bacteria—Acetic Acid Bacteria—Yeasts—Molds—Enzymes.

We have devoted much space to the deleterious effects of micro-organisms, enzymes and fermentative changes in general on our foods. It may surprise, therefore, to find that man has learned to use certain of these changes for preservation purposes. This has been accomplished, principally, by selecting certain microscopic organisms which produce preservative substances harmless to man and allowing these organisms to propagate in the food to be preserved.

Most of the methods of this class have been slowly developed through the centuries without a scientific knowledge of cause and effect. By the application of the sciences of bio-chemistry and bacteriology a great deal of progress has been made, and in many industries preservation by fermentation changes is on a rigidly controlled scientific basis.

Micro-organisms, and every other living thing for that matter, obtain nutriment and energy for development and maintenance by causing changes in the chemical

composition of their food supply mainly by means of enzymes. In dealing with fermentation changes, destructive or beneficial, we must consider enzyme action primarily. This is true, whether the enzymes are excreted by growing micro-organisms or are a normal constituent of the food product itself. In most of the fermentation processes useful in preservation micro-organisms are used. In a few, the natural enzymes contained in the food are utilized, usually in combination with a chemical preservative.

Representatives of all three classes of micro-organisms, bacteria, yeasts and molds, are made use of in fermentation. Among the bacteria the ones which are most useful are those that produce lactic acid in comparatively large quantities. We are all familiar with these organisms in sour milk. Most lactic acid producing bacteria multiply very rapidly, and since small numbers of them are present in even the purest milk it is inevitable that they should soon outnumber all other forms. As soon as a small percentage of lactic acid has been developed, it acts as a preservative against most other forms of microscopic life.

In practical food preservation the lactic acid bacteria are used for the purpose of preserving sauer-kraut, ensilage for cattle food, in cheese making and to a certain extent in the brewing industry. In almost every case where preservation is effected by lactic acid organisms, a small amount of salt is added for the purpose of holding the undesirable bacteria in check until the lactic acid producers have had time to develop enough acid for preserving purposes. This object may be obtained also by

inoculating the food with large amounts of specially prepared pure cultures of lactic acid bacteria, which have been scientifically selected for the purpose.

In cheese making many bacteria other than lactic acid formers undoubtedly play a large part. The many and diverse flavors of cheeses are obtained by varying the conditions of manufacture to favor the growth of the desired bacteria. This is accomplished by varying the amount of salt and other constituents added and by varying temperature, humidity and other storage conditions. Other micro-organisms, besides the bacteria, may also play a part.

Another very important class of bacteria, from the standpoint of preservation, are those which produce acetic acid in quantity from alcohol. The commonest of these, known as mycoderma aceti, grows rapidly on the surface of alcoholic solutions which are exposed to a plentiful supply of air and secures its supply of life-developing energy by causing a chemical reaction between alcohol and the oxygen of the air. This reaction results in the formation of acetic acid and when the alcohol is exhausted may continue with the formation of carbon dioxide and water. However, if the supply of air is cut off when the change to acetic acid is complete the acid solution, or vinegar, will remain *in status quo* for as long as desired. This is the ordinary process of making vinegar.

Vinegar thus made not only remains preserved but has the property of being able to preserve other foods, as we have learned in the chapter on "Chemical Preservatives."

The yeasts supply a very important member to the list of preservative micro-organisms. This is saccharomyces cerevisæ or common yeast, the agent of fermentation in bread making, brewing and alcoholic fermentation in general. In bread making yeast is used primarily as a leavening agent but undoubtedly its ability to grow rapidly and produce preservative substances is of help to the keeping qualities of the product. This is shown by the fact that when bread is made with contaminated yeast or under unsanitary conditions, a sour or "slimy" product frequently results. If the yeast develops normally the bacteria causing sourness or sliminess are overgrown and held in check.

In the alcoholic beverage industry we find the greatest development of fermentation preservation. While not usually thought of as such, alcoholic beverages are true instances of fermentation preservation for the reason that the agent of preservation is alcohol produced by the fermenting organism, yeast, from sugar in solution. The common yeast possesses the remarkable ability of producing up to seventeen percent of alcohol in sugar solutions containing the proper yeast nutriment and this is sufficient to preserve the liquid against practically every known agent of spoilage except the vinegar producers. If air is excluded of course this cause is eliminated also and thus we are able to have wines many years or even decades old. In producing alcohol yeasts also produce an almost equal weight of carbon dioxide gas and this also has valuable preservative properties in addition to being a great improver of flavor in many beverages.

Yeasts are by no means the only micro-organisms that produce alcohol. In Japan practical use has been made of a mold that will produce even higher concentrations than the yeasts. Other micro-organisms may also produce small quantities of alcohol but not in amounts that justify practical application.

The Chinese and Japanese also use a mold for preparing their "soy" sauce which we know as a constituent of "Worcestershire Sauce." This mold is allowed to grow on the surface of particles of dough made from wheat bran, soy beans, etc., and after a suitable period of incubation the entire mass is macerated in water. Under these conditions a great deal of the carbohydrates and proteins are hydrolyzed or broken down into simpler water soluble compounds, which form, with the water, a sauce which is greatly esteemed by Oriental people. Molds are also used in the manufacture of cheese, one in particular, known as penicilium roqueforti, being the cause of the characteristic flavor of Roquefort cheese. Other molds not so well studied undoubtedly have a part in the development of flavor and in the keeping qualities of cheeses.

The fermentation changes which have been described in this Chapter are all initiated by micro-organisms.

Another class of fermentation changes with preservative effects depends on the natural enzymes contained in practically all of our foods. A characteristic example of this change is found in ordinary salted anchovies and sardines. These fish are heavily salted and kept for several months weighted down in small containers at temperatures of from 60 to 70 degrees Fahrenheit. As a

result of this treatment changes go on in the fish which cannot be attributed to micro-organisms but only to enzymes naturally contained in the flesh of the fish. These changes take the form of a change in color to a brownish red all through the flesh and the development of a characteristic flavor and consistency.

The curing of tobacco is another instance where enzyme changes exert a great deal of beneficial influence. The tobacco leaf, and leaves in general, are particularly rich in enzymes which retain a large part of their activity even after drying. These enzymes only require water and favorable storage conditions to resume activity and by this means the tobacco manufacturer controls, to a great extent, flavor and color changes.

CHAPTER XII

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED) — HERMETIC SEALING

Definition of Hermetic Sealing—Effectiveness of Hermetic Sealing—Classification of Hermetic Sealing Methods—Simple Hermetic Sealing—Hermetic Sealing in a Partial Vacuum—Hermetic Sealing with Inert Gases.

Hermetic sealing is not usually considered as a distinct method of preservation for the reason that it is so generally associated with heat sterilization that the two methods are considered as one. It will be shown here, however, that hermetic sealing alone has distinctive preservative characteristics and that it, therefore, deserves separate classification and consideration.

An ideal hermetically sealed container may be defined as a container sealed so thoroughly that not a single atom of matter can get in or out. This condition is seldom attained in a food container and therefore we must be satisfied with a less rigid definition. For practical purposes we may define a hermetically sealed food container as one which can retain an air pressure of one pound per square inch while submerged under water, without showing visible leakage. As a matter of fact, there are so many styles and types of containers that they vary in tightness from the almost ideally hermeti-

cally sealed to those which are visibly leaky. Our empirical definition is only for the purpose of drawing a line as fairly as possible between containers which we can call hermetically sealed and those which are obviously not.

In speaking of hermetically sealed food containers we are confined practically to those made of metal and glass. Other materials, such as rubber, gelatine, cork, glycerine, etc., are used to assist in making closures, but we must depend on these two principal materials for imperviousness to gases from without and within.

The only metal container which is of importance as a hermetic food container is the tin can, so that really we are limited to containers of tin plate and glass. Both these materials serve their purpose well and the choice between them must be made on other considerations than their efficiency in preserving a hermetically sealed condition.

In sealing a food hermetically it is almost impossible to prevent sealing a certain amount of air in the container. This has been found to be a disadvantage to many products and a great deal of experimental work has been done to overcome the difficulty. As a result of this work, methods have been evolved for sealing in vacuum and in an atmosphere of chemically inert gases such as nitrogen and carbon dioxide. Each of these methods has advantages which merit separate discussion. Therefore we may divide our subject into three parts as follows:

1. Simple hermetic sealing.
2. Sealing in partial vacuum.
3. Sealing in inert gases.

The effectiveness of simple hermetic sealing against the various agencies of spoilage may be briefly summarized as follows:

1. It is entirely effective against animal pests.

2. It is effective against the entrance of insect pests but does not prevent the development of eggs or living insects enclosed in the container with sufficient air to support life.

3. The development of bacteria, yeasts and molds are not sufficiently held in check to be of practical value.

4. Enzyme action is not retarded except where oxygen plays a part and then only to the extent that oxygen is excluded from the container.

5. Oxidation changes are inhibited to the extent that oxygen is excluded from the container. In some cases hermetic sealing is sufficient in itself to prevent oxidation changes. In others the oxygen sealed in the container causes serious trouble. Changes due to light are prevented in metallic containers but may proceed in those made of glass. Some containers are made of colored glass to cut off the more active rays of light. Most colloidal changes are unaffected but some, due to evaporation, are prevented for the reason that the evaporation itself is prevented. Absorption of water from the air is, of course, impossible in a hermetically sealed container.

6. Contamination with foreign substances is for the most part, prevented though some foods become contaminated to a slight degree from the walls of the container.

It is obvious from the above summary that only foods that are exempt from spoilage by micro-organisms can be preserved by hermetic sealing alone. Dehydrated foods and food products which are naturally water free fall into this class and therefore may be greatly benefited by simple hermetic sealing in a metal or glass container.

We have already noted that the dry cereal and legumes, as a class, present a comparatively simple preservation problem. They are proof against most causes of spoilage and require very little in the way of protection. Hermetic sealing with its necessarily expensive containers finds little application in this field. However, under special climatic conditions where the humidity is high and where insects are prevalent, the more expensive prepared cereals, oatmeal, for instance, are sometimes packed in tight tin cans. This method does away with all trouble from humidity conditions and prevents insect infestation from outside the container, but if the eggs of the insect are packed with the product, enough air is usually sealed into the container to allow the eggs to hatch and carry on the life cycle of the insect.

Shelled nuts are greatly benefited by hermetic sealing. Nuts, however, are so subject to oxidation damage that every effort must be made to eliminate oxygen from the container. For this reason, the vacuum and inert gas methods of packing are preferred and practically all the nuts packed in small containers are put up by one

method or the other with the inert gas system rapidly increasing in popularity.

Fresh vegetables and fruits are subject to rapid spoilage by micro-organisms and therefore cannot be kept for more than a few days by hermetic sealing alone. Hermetic sealing in combination with sterilization has very extensive application in this field and will be discussed in the next chapter. When fruits and vegetables are dried enough to stop the development of micro-organisms, then simple hermetic sealing may be used very effectively to check the changes which are still likely to occur.

Hermetic sealing, alone, is obviously of no benefit in the preservation of fresh meats and other flesh foods. When these foods are salt-cured or smoked, however, hermetic sealing may prevent some very disagreeable changes. Where cured meats are to be shipped for long distances or packed for military use hermetic sealing has often been used to great advantage.

Hermetic sealing alone offers no advantages in the preservation of fresh milk and cream but has become standard in the packing of sweetened condensed milk and dried milk. In the latter product it will be superseded by the inert gas method of packing for the reason that this method offers the simplest means for thoroughly eliminating the damaging oxygen from the container. Butter has also been packed in hermetically sealed containers for export shipment with some advantage. The causes of spoilage of butter are so numerous and complicated, however, that uniform results cannot be expected.

Hermetic sealing is not used in the preservation of eggs

and egg products though there is certainly a field for it in "powdered" egg. A great many efforts have been made to convert the shell of the egg into a hermetically sealed container by various means and with some success though the methods developed have never been generally applied.

In the field of refined and "manufactured" foods the method of hermetic sealing finds extensive application. The purified carbohydrates, the starches and sugars do not need hermetic sealing but it has become the general method of preserving edible oils for the individual consumer. Millions of pounds of olive oil, refined corn, cottonseed and peanut oils as well as lard compounds are carried to the consumer protected by a hermetically sealed glass or metal package.

Hermetically sealed packages are also becoming extensively used by bakers and confectioners whenever their products are to be exposed to hot, humid air or other damaging climatic condition. The hermetically sealed package is particularly adapted to the export trade.

In the beverage industry hermetic sealing has its greatest application. The bulk of the worlds manufactured beverages, whether alcoholic or non-alcoholic, are delivered to the consumer in hermetically sealed containers. With alcoholic beverages, the principal objects are to prevent evaporation and contamination with foreign substances. This is accomplished almost perfectly by the hermetically sealed glass bottle. Non-alcoholic beverages must contend with evaporation and contamination as well as the action of micro-organisms

and of course, other means of preservation must be used in conjunction with the sealing. As we have noted in the Chapter on Chemical Preservation, bottling with carbon dioxide gas under pressure is a favorite auxiliary method in this field. Heat sterilization is an alternative method.

Tea, coffee and cocoa are all subject to loss of flavor by evaporation and to spoilage by climatic conditions. They are therefore particularly benefitted by hermetic sealing and this method is being used extensively wherever the risk of spoilage warrants the added expense.

Hermetic Sealing in Partial Vacuum

The deleterious effect of air on foods was observed at a very early date. It was a logical development of this observation to attempt to seal foods in a vacuum for preservation purposes. A great amount of work has been done in the attempt to make a reliable vacuum food container and a great deal of progress has been made in that direction but on account of the mechanical difficulties in the way the goal is still far from realization. Because of the uncertainty of maintaining the vacuum the only foods which are vacuum packed are those which keep fairly well under simple hermetic sealing. If the container does not hold the vacuum the preservation may not be as good as if the vacuum had been maintained but the food is seldom inedible.

Supposing that a partial vacuum is maintained, that is, that part of the air in the container has been removed and kept out, the advantages of vacuum packing over simple hermetic sealing may be summarized as follows:

1. Vacuum packing reduces oxidation spoilage or rancidity in proportion to the amount of air that is removed and kept out of the container.
2. It reduces the chances of certain micro-organisms developing by cutting off part of the air supply.
3. It is a partial safeguard against insect development for the same reason.

These few advantages taken into consideration with the demonstrated unreliability of the containers give vacuum packing very little excuse for being, but still it has maintained a foothold in several fields. Large quantities of shelled nuts are packed in vacuum both in glass and tin containers and have met with favor by the consumer. Where the containers are reasonably reliable and where the nut-meats have been fresh and dry when packed, the product has been known to keep almost unchanged for years. When the containers leak, air gets in, and the nuts soon become inedibly rancid.

Salt-cured and smoked meats have also been popularized in vacuum containers, sliced bacon being particularly successful. Here, again, the reliability of the container is most important and where serious leakage of air into the container occurs, spoilage may be expected to follow shortly.

Another vacuum packed product which has attained great favor with the public is ground coffee. Roasted coffee contains highly volatile essential oils as well as fixed oils which are subject to rancidity. The combination of a hermetically sealed can and the removal of most of the contained air is very effective in preventing evapora-

tion of flavoring oils and the development of rancidity or "staleness." Coffee has the peculiar property of giving off a large volume of gases immediately after wasting. These gases consist principally of carbon dioxide and carbon monoxide in the proportion of about nine parts of the former to one of the latter. When coffee is vacuum sealed within a few hours after packing, the gas soon fills the vacuum and generally builds up a pressure in the can. This is a fortunate circumstance in the packing of coffee as the tendency for tin cans to draw air inside is of course obviated. Within a few hours, therefore, "vacuum packed" coffee becomes "inert-gas packed" coffee with many of the advantages that inert gas packing has over vacuum packing.

Vacuum packing has been used quite extensively in the preservation of tobacco. For this purpose a method of packing has been devised called the "heat-vacuum" process. In this method the tobacco is simply sealed in a metal container, the top of which has been vented with a small hole. The can is then put in a heated chamber and allowed to remain until thoroughly warmed. While still warm, the vent is soldered and when the can is cooled the contraction of the remaining heated air causes the development of a partial vacuum. The vacuum obtained by this method is so slight that it can have little, if any, effect on the keeping qualities of the tobacco. The effectiveness of the "Heat-Vacuum" process is probably due to the sterilizing effect of the heat treatment on molds and the eggs of insects. The "mechanical-vacuum" method has also been tried on tobacco with success by some manufacturers and failure by others. Much

higher vacuum can be obtained by mechanical means than by heat treatment, but, of course, the heat sterilizing feature is eliminated.

Hermetic Sealing with Inert Gases

The effectiveness of inert gas packing has been a matter of much controversy. It has been alternately advocated and condemned for a half century. The advocates of this method of packing have undoubtedly been its worst enemies. Being, for the most part, ignorant of the elementary principles of the sciences governing food preservation, they have usually jumped to the conclusion that their particular method of packing was universal in its application. Of course, their claims could not be substantiated by results and their methods, often of some merit, fell into disrepute.

A study of the possibilities of inert gas packing, that is packing foods in an atmosphere of carbon dioxide or nitrogen, shows that the process has many meritorious points and mechanical development by practical technical organizations is rapidly demonstrating that these good points may be commercially applied to great advantage.

As with vacuum packing, the primary object of inert gas packing is to remove as much air as possible from the container and to prevent more air from entering. These objects can be accomplished more simply with gas than with vacuum for several reasons. Gas packing is usually accomplished by first withdrawing the air from the container by a highly efficient vacuum pump and then allowing this vacuum to be filled by the pure gas from

a supply tank. While this operation is carried out the food container is sealed with the exception of a small hole through which the air is withdrawn and the gas allowed to enter. After filling, the container may be brought out into the air and sealed without appreciable loss of gas. This is a very great advantage mechanically, since the containers do not have to be sealed while out of sight as with mechanical vacuum systems. The fact that the gas is put in at atmospheric pressure is also a very great advantage as the containers are not submitted to the high pressures, up to fourteen pounds to the square inch, that must be borne by vacuumized vessels. With these advantages it is possible, with gas, to obtain the equivalent of twenty-nine inches or more of vacuum without submitting the can to more than a few ounces of pressure at any time.

In addition to these advantages carbon dioxide has certain positive properties which make its use very desirable for many foods. In the chapter on "Chemical Preservation" we have discussed the preservative properties of carbon dioxide under high pressure. At atmospheric pressure, carbon dioxide is not a positive germicide but has marked ability to restrain the growth of a particularly damaging group of micro-organisms, the molds. It also has the property of preventing all development of insect life and to kill larval and adult forms after a few hours' exposure. Recognition of these and other desirable properties is attracting attention to the possibilities of inert gas packing and great progress is to be expected in this field in the next few years.

The development of gas packing has already reached

the commercial stage with nut-meats, dried milk and in the cracker-baking industry. It has excellent prospects for growth in the packing of breakfast foods for export, dried fruits and vegetables, cured meats and fish, butter, cheese, dehydrated eggs, candy, edible oils and all forms of tobacco.

CHAPTER XIII

FOOD PRESERVATION METHODS AND PROCESSES (CONTINUED)—HEAT STERILIZATION AND PASTEURIZATION

Definition of Terms—Effectiveness Against Causes of Spoilage—Canning of Vegetables—Fruits—Flesh Foods—Milk—"Pasteurization" of Milk—Canning of "Prepared" Foods.

No invention has been more important to the advancement of our civilization than the discovery of the relationship of micro-organisms to disease and the decay of organic matter. Pasteur not only gave us this gigantic discovery but also a very effective weapon against our minute enemies, namely, heat sterilization or Pasteurization. Of late years the term pasteurization has come to mean a limited heat treatment to kill dangerous disease germs only and in this sense we shall use it here. The substantially complete destruction of all life by heat we shall call "sterilization."

The process of sterilization for food preservation purposes is so generally used in connection with hermetic sealing that we are accustomed to think of them as inseparable. For practical commercial purposes this is almost true and yet it is possible to obtain and retain complete sterilization without the help of a hermetically sealed vessel. If a bottle or other open container is

filled with any food product, loosely stoppered with cotton and thoroughly sterilized it will remain so indefinitely although air is free at all times to pass back and forth through the cotton wool. The food will remain preserved against contamination with micro-organisms by the filtering action of the cotton.

Heat sterilization is primarily a weapon against micro-organisms but we have already learned that the means which can circumvent these minute enemies are often effective against the other causes of spoilage as well.

The hermetically sealed containers in which all commercially sterilized foods are packed are proof against the entrance of animal and insect pests and the sterilization treatment is always sure to kill the eggs of insects that may be in the food before packaging. Micro-organisms in the food are disposed of by the heat of sterilization and the entrance of others prevented by the sealing of the container. Enzyme activity is almost entirely halted by the heat treatment and ceases to cause trouble. As a matter of precaution, canned foods are usually heated either before canning or in the container before closing, resulting in the elimination of most of the air in the foods and the troubles that go with it. Evaporation, humidity, light and most other chemical and physical causes of spoilage are halted by the hermetic sealing. About the only change of a chemical nature that remains to trouble the canner after he has properly closed and sterilized or "processed" the container is the action of the food product itself on the walls of the container. With glass vessels this action is not serious but with tin cans, it is the cause of a great deal of damage. All canned goods,

almost without exception, have some chemical action on the tin plate of which "tin" cans are made. With many foods, this chemical activity produces no damaging result and is unnoticed. With others it is so serious that many canners refuse to risk packing them in tin cans. The most serious effects of chemical actions of this type are:

1. Corrosion of the can and solution of the tin and iron in the food.
2. Actual perforation of the can.
3. Blackening of the interior of the can, the "black" sometimes transferring itself to the food.

Corrosion of the can occurs with most foods but is serious only with those that are very acid and a certain class of practically neutral vegetables of which squash and asparagus are representative examples. The acid action which corrodes cans also tends to bleach highly colored fruits, berries and vegetables and with these products a specially prepared enameled tin is used.

The exact cause of perforation has long been a mystery but now a great deal of the trouble has been traced to oxygen in the can. Canned apples, cherries, and berries in general are the principal offenders. Some of the trouble with perforations has been attributed to the coloring matter in the case of colored fruits but the connection, if any exists, is obscure and has never been proved.

Blackening of the interior of tin cans is due principally to hydrogen sulphide gas in high protein foods and some vegetables and to oxygen in some others. Hydro-

gen sulphide causes the most trouble in the canning o meats, fish and corn. This type of blackening has bee fought with paper lined cans and careful selection o materials with more or less success. More satisfactor means of controlling this trouble are being sought Oxidation black is not such a serious problem. It ma usually be solved by care in elimination of air from th product by heat treatment and care in filling and closin the container.

Fortunately the above described chemical reaction go on very slowly, and most canned foods enter con sumption before damage is done. Like all chemica reactions these are accelerated by high temperature an therefore temperature of storage must be taken int account in cases where corrosion and blackening ar likely to occur.

We may conclude from this discussion that heat ster ilized, hermetically sealed foods are proof agains practically every form of spoilage for a reasonabl length of time and that therefore this method of pre servation is probably, the most secure of all methods.

It is also positive and subject to almost scientifi precision in application, and is therefore supersedin other less secure methods by leaps and bounds.

We have noted that sterilization by heat is primaril a method of combating micro-organisms. Since micro organisms cannot develop in and spoil foods unless wate is present, we may eliminate dried cereals, legumes an nuts from consideration. Coconut meat in the wet stat is canned by methods similar to those followed in th canning of vegetables.

Foods in the "vegetable" class form one of the great divisions of the canned food industry. Heat sterilization and hermetic sealing are particularly suited to the preservation of vegetables, since all of them contain large quantities of water and are therefore very prone to spoilage by micro-organisms. Most vegetables are practically neutral in reaction and are therefore susceptible to spoilage by very heat-resisting forms of bacteria. Heat treatment must therefore be very severe in order to insure keeping. Asparagus, corn, peas, string beans, artichokes, spinach, mushrooms and other vegetables of this "neutral" class are usually sterilized in closed steam retorts at temperatures of from 230° to 250°F. and for from twenty minutes to three hours' time depending on the size of the can and the ease with which heat can penetrate to the center. Both glass and tin containers are used for vegetables but the tin can is preferred on account of its cheapness, ease of handling and general all-around suitability for the purpose.

Canned fruits form another of the great divisions of the canning industry, being about on a par in importance with the vegetables. Fruits are sufficiently acid in reaction to prevent the development of heat-resisting bacteria and therefore a very mild treatment is needed in comparison with the "processing" of canned vegetables. Tomatoes, while usually considered in the vegetable class, may be accounted a fruit for canning purposes. A mild heat treatment is sufficient to preserve them on account of their comparatively high acid content. Ripe olives, on the other hand, act like vegetables towards canning processes and must be severely "pro-

cessed" to remove danger of spoilage and the development of the very poisonous Botulinus bacillus. Peaches, plums, pineapples and apricots are comparatively easy to pack, corroding the can very little and seldom perforating. Apples, cherries and berries generally are considered difficult to pack in tins on account of perforation, corrosion and the attendant development of hydrogen gas. The hydrogen gas is a product of the chemical action of the fruit acids on the tin plate and gives the appearance of a swollen can due to bacterial or yeast spoilage. Otherwise the contents of the can are little affected by it.

Enormous quantities of fruit are packed by housewives in glass containers for home use. Manufacturers also pack fruits in glass but in nothing like the volume that is put up in tin.

Meats, fish and shell fish are packed in very large volume, though the bulk of these foods is handled by refrigeration and other methods. Refrigeration and salt curing methods have been so carefully worked out on meat products that there is little need to resort to the more expensive sterilization-hermetic sealing processes. Specialties, such as deviled ham, potted tongue, veal loaf and others have attained a wide distribution. Other more staple meat products are canned for military use and for export trade.

The fish which are canned in largest volume are salmon, sardines and tuna. Other fish are packed to a limited degree only. The shell-fish are represented by lobster, shrimp, crabs, oysters and clams of various species. All flesh foods, whether of animal or marine origin tend to

give off hydrogen sulphide in the can and therefore to cause blackening. Lobster, shrimp and certain kinds of fish are the worst offenders in this respect and manufacturers have almost universally adopted paper lined cans for protection. Glass containers are effective in preventing the development of black but are difficult to sterilize, expensive and adds greatly to the shipping weight.

The largest single canned product in terms of both value and volume is milk. Evaporated and condensed milk together almost equal in volume all other canned foods packed in the United States. Unsweetened evaporated milk is a true example of the heat-sterilized hermetically sealed method of preservation. Sweetened or "condensed" milk does not, strictly speaking, belong in this class. It is more properly an instance of sugar preservation combined with hermetic sealing. Though heat is used in its preparation it is for evaporation purposes and does not result in complete sterilization.

Another method largely used in the handling of milk is "pasteurization" a mild heat treatment given for the purpose of killing dangerous disease germs. This process has undoubtedly saved millions of lives from such diseases as tuberculosis, typhoid and enteric disorders, and Pasteur's fame would rest secure if based on this discovery alone. In practice the method is applied by bringing the milk to a temperature of about 145°F. and holding twenty minutes or more in suitable vats or coils. It is then rapidly cooled and sold within the next few days, being kept refrigerated meanwhile. Pasteurization kills the bacteria that cause milk to sour as well as disease

germs but leaves the heat resistant putrefying organisms. For this reason pasteurized milk putrefies rather than turns sour if held at room temperature for a day or more.

Of late, a process has been devised for canning certain kinds of cheese by heat sterilization. Cheese packed in this way has been well received by the public but the volume is very small compared with the amount marketed otherwise.

All foods of animal origin are practically neutral in reaction and therefore require the same severe sterilization treatment given vegetables. This property in both animal and vegetable foods may be changed by the addition of slight amounts of a suitable acid but although this method has commercial possibilities it has not been practically applied except in a few instances.

There are few instances of heat sterilization methods being applied among the manufactured foods. Fruit syrups for the beverage industry are canned and bottled but these products really are in the canned fruit class.

However there are some canned foods which we have not yet had occasion to discuss and which probably belong in the class of "manufactured" foods since they contain many ingredients assembled and packed in factories. This group includes the canned soups, puddings, and other prepared dishes intended to be served from the can with little preparation.

The soups, of course, contain large quantities of water and, since their principal solid constituents are meats and vegetables, are neutral in reaction. Therefore they require a severe heat treatment for sterilization unless a large amount of acid substance, tomatoes for instance, is

present. From the technical standpoint soup canning presents few difficulties.

Canned puddings, of which plum pudding and fig pudding are the commonest examples, contain so much fruit and sugar that they require very little heat treatment. The heating is often prolonged beyond the needs of sterilization for the sake of flavor development. The canning of puddings and similar foods is also very simple from the technical standpoint.

The possibilities of canning new ready prepared dishes are endless and food packers are constantly experimenting with this end in view. Ready prepared salads and desserts are among the obvious possibilities and there is little doubt that these will be developed in due course of time.

CHAPTER XIV

COMBINATION PRESERVATION METHODS

Methods Used in Combination—Refrigeration and Dehydration —Refrigeration and Chemical Preservation—Refrigeration and Hermetic Sealing—Dehydration and Chemical Preservation—Dehydration and Hermetic Sealing—Chemical Preservation and Hermetic Sealing—Hermetic Sealing and Sterilization—Other Combination Methods.

In our discussion of the general methods of food preservation we have pointed out that each of the methods is effective against certain causes of spoilage, but ineffective against others. We have also remarked from time to time that certain foods could be preserved by combinations of two or more of the preservation methods. It is the purpose of this chapter to point out the principles governing such combination methods and to indicate when the application of the combination of two or more methods is advisable.

As a general principle it may be stated that when two or more methods of preservation are applied to a food product their qualities of preservation are additive. For instance if a food sealed in a hermetically sealed container be put into cold storage, the food so preserved will have the benefit of the preservative effect of both methods of preservation. Of course, it must be assumed that the food in question can stand, without injury, the applica-

tion of all the preservation methods to be used in combination.

We have already noted that the first method of preservation on our list, simple storage, is used in combination with every other method. For the purposes of our discussion therefore we may dismiss simple storage from consideration by taking it for granted that every method of preservation includes simple storage for the purpose of protection from the elements, thievery, etc.

Any desirable combination of food preservation methods may be made, none of them being essentially incompatible with another. The number of combinations possible is therefore very large. It is not possible here to go into all of them, but a short discussion of the application of some of the commonly used combinations may be instructive.

Refrigeration and Dehydration.—Dehydrated fruits and vegetables derive great benefit from storage at low temperatures. This combination is effective against almost every form of spoilage and those which can proceed, do so at a greatly reduced rate. Partly dried flesh foods, powdered milk and eggs also benefit greatly by the combination of dehydration and refrigeration.

Refrigeration and Chemical Preservation.—These methods are very successfully combined in the case of salted and smoked meat and fish, the combination preserving the product as long as desired, and the chemical preservation being depended upon for preservation after removal from storage.

Refrigeration and Hermetic Sealing.—The combination of low temperature storage and hermetic sealing is very

effective in the case of shell fish, fruit juices and other products containing large amounts of water. The chief drawback is the quickness with which the product spoils after removal from storage.

Dehydration and Chemical Preservation.—This combination has many possible variations on account of the large number of chemical preservatives used. Dehydration, partial or complete assists in the keeping of such products as smoked and salt cured meats and fish, sugared fruits, and foods to which objectionable preservatives such as sulphur dioxide are added.

Dehydration and Hermetical Sealing.—This method is very effective and the combination should be used on a large percentage of dehydrated foods. The combination of dehydration with hermetic sealing in an atmosphere of inert gases is particularly effective and its use will no doubt be rapidly extended. Dried fruits, vegetables, milk and eggs are in great need of hermetic sealing in gases as an auxiliary preservative method.

Chemical Preservation and Hermetic Sealing.—Many of the chemically preserved foods are greatly benefitted by being packed in hermetically sealed containers. Foods of this class are subject to severe damage by atmospheric action and this, of course, may be well controlled by a suitable hermetic sealing process.

Hermetic Sealing and Sterilization.—This is one of the very important combination methods, the value of foods thus packed running into billions of dollars annually. This is the combination by which all canned vegetables, fruits, meats, fish and milk are packed. This is probably the method by which the most complete protection

against all causes of spoilage is obtained and this fact alone is sufficient to impress us with its vast value to our civilization.

Combinations of three or even more of the methods of preservation are of value in the case of some foods that need not be discussed here. The important fact to be emphasized at this point is that these preservation methods, singly and in combination are the instruments and the only instruments, with which we must work in the preservation of our foods and that by careful study and experiment a suitable process for any food may be built on a foundation of these essential methods.

CHAPTER XV

FOOD CONTAINERS

Classification of Containers—Elevators, etc.—Tanks—Barrels, etc.—Cases—Bags—Cans, etc.—Bottles, etc.—Cartons and Packages.

We have already had occasion to refer to the influence of the container on the keeping qualities of many foods but it will undoubtedly fix the characteristics of the various types of containers more firmly in our minds if we discuss them systematically.

Our discussion, to be at all complete, must include, a wide range in type, size and cost for we must include reinforced concrete grain elevators holding thousands of tons of grain as well as the waxed paper wrapper of a "penny" piece of candy. The following is an attempt to classify the types in general commercial use and the materials from which they are made.

1. Elevators, silos, etc.—constructed of reinforced concrete, steel, wood, brick and stone.

2. Tanks—made of concrete, wood, steel, both coated and uncoated, and copper.

3. Barrels, hogsheads, kegs, tubs, pails, drums, etc., made of wood and steel.

4. Cases, crates, baskets, etc., made of wood.

5. Bags, bales, etc., made of burlap, cotton, matting, paper, etc.

6. Cans, canisters, etc., made of iron, galvanized iron and tin plate.

7. Bottles, jars, jugs, etc.—made of glass and earthenware.

8. Cartons and packages—made of paper combined with adhesive, water-proofing materials, etc., and metal foil.

It would be very interesting to discuss this subject in many of its other aspects, but it is necessary, here, to confine ourselves to the standpoint of preservation.

Our first class which includes the large storage containers for solid foods, is depended on for protection against the elements and animal pests and to a certain extent against insects. The foods which are stored in them must therefore have means of protection against the other causes of spoilage. In general, the foods which are stored in elevators, large bins, etc., are dried cereals, or legumes which have a high natural resistance against most causes of spoilage. Elevators or bins made of concrete or metal are more secure against animal pests and insects than those made of wood, and therefore the modern tendency is to go to the more secure method of construction.

Tanks are, of course, primarily for liquid foods and may be depended upon for the same protection as the

containers of class 1. In addition, however, a closed tank may be relied upon for protection against evaporation and other chemical and physical changes due to the atmosphere. Edible oils, molasses, syrups, etc., are commonly stored in steel tanks for long periods at ordinary temperatures. Concrete tanks are also coming into use for this purpose. Wooden tanks are no longer considered suitable. For delicate foods liquids such as milk, cream, sauces, salad dressings, etc., glass-enamel lined tanks have been developed. These tanks are often placed in insulated rooms under artificial refrigeration.

Tight barrels, hogsheads, drums, kegs, etc., the containers of class 3, have the same preservative characteristics as tanks. Wooden barrels, no matter how water tight, cannot be relied upon for protection against evaporation where used to contain volatile liquids. Even when the barrel is tight enough to hold a pressure of several pounds to the square inch evaporation takes place through the wood.

The barrels that are used as containers for dry substances such as sugar and flour, or for fruits and vegetables such as apples and potatoes, offer no protection except from theft and mechanical injury and, to a limited degree, from animal and insect pests.

Cases, crates, baskets and other wooden containers are similarly inefficient from the standpoint of preservation. For foods which can resist spoilage for reasonably long periods they offer a cheap means of transportation which is taken advantage of to an enormous extent.

Wooden cases are also used extensively as containers for small metal, glass and paper packages. Here the

question is only one of preserving the package against mechanical injury.

The ordinary burlap cotton or paper bag of class 5, may be considered as having practically no preservative characteristics. It simply serves as a container and offers little or no protection from theft, mechanical injury, animals or insects. However, bags are the cheapest containers obtainable and therefore are used wherever the keeping qualities of the food will allow.

Of late years considerable progress has been made in developing bag liners with water and greaseproofing qualities. Burlap bags have actually been lined with an almost continuous coat of rubber, making them practically rain-proof. This is a very fertile field for development and great progress will no doubt be seen in the next few years.

Metal cans and canisters made of tin plate, find vast application as food containers. Those made of galvanized iron and ordinary black iron are used to a limited extent.

With regard to preservative properties cans may be divided into three classes, those hermetically sealed, those hermetically sealed with the exception of the top or closure and those in which no attempt is made to make the seams air tight. Hermetically sealed cans are made by soldering all seams or by seaming the metal sheets together with the assistance of rubber and other forms of gasket material so thoroughly that the passage of gases into or out of the container is prevented. In practice a combination of both soldering and "seaming" methods has resulted in the development of the "sanitary" can in

which practically all of the world's supply of canned meats, fruit and vegetables is packed. The preservative properties of such containers have been discussed in the chapter on Hermetic Sealing and need not be gone into here.

The second class of metal containers includes those cans in which the advantages of absolute hermetic sealing have been sacrificed to ease of opening. These cans are made in the same way as those hermetically sealed with the exception of the closures which are of many and varied types. These closures are known as "Friction tops," "Slip covers," "Screw tops," and by numerous coined trade names.

Cans of this type are used for syrups and other food liquids, spices, cereals and many other foods which do not require sterilization or other drastic means of preservation. They are inferior to hermetically sealed cans for the reason that air goes in and out with changes of temperature through the imperfect closure by a sort of breathing action. Thus foods are brought into contact with limited amounts of air every day, and those subject to oxidation, humidity and other physical and chemical spoilages due to air are injured.

The third class of cans, those in which no effort is made to have the seams tight, are of course even less protection against air damage. The air may pass more freely into and out of these cans by gravity changes in addition to changes produced by temperature and pressure. Thus, in a can containing cereal stored in a room in which the temperature is suddenly lowered, warm air will rise and be replaced by cold air coming in at the bottom.

This air, in turn, becomes warmed by the cereal and rises, causing complete changes of air in the containers in a short time.

Cans of this class are frequently sold to food manufacturers as "air-tight" and used for coffee, spices and innumerable other products. Spoilage and loss of flavor are so common that deterioration of this class of goods has been erroneously accepted as inevitable.

In spite of their many shortcomings, however, this class of containers has many advantages over paper cartons and other porous containers. The almost continuous metal sheet keeps the product from complete contact with air and therefore protects to a great extent against damage from humidity or from excessively dry air. This type of can does not protect against oxidation, however, for there is always enough air present to cause the maximum damage from this cause.

Class seven, which includes all containers made of glass and non-porous earthenware, may be compared in preserving efficacy with the first two sub-divisions of the metal container class. Tightly corked bottles, vacuum sealed jars and other air-tight glass containers may be compared with the hermetically sealed metal vessels. Bottles and jars sealed with screw tops and other easy-opening closures fall into the same class as the "friction top" and "screw top" tins. Glass and earthenware containers are superior, however, in one respect. Metal containers are rapid conductors of heat and for this reason a product containing water will cause the inner surface of the container to condense water vapor or "sweat" when the temperature is lowered. Glass con-

tainers are comparatively good heat insulators and are not open to this objection.

Boxes, cartons and bags made of paper have been used for centuries as food containers with little thought other than to protect from dust and dirt and to provide a convenient cheap package. These are still the principal reasons for the widespread use of paper containers although of late years, great improvements have been made in the protective qualities of paper. Waxed papers have been developed which are quite efficient in protecting against excessive humidity and quite satisfactory greaseproofing qualities have also been secured. It must be understood, however, that no paper container can be considered *equal* in protective qualities to those made of metal even when the joints of the metal containers are only lightly clinched together. This is on account of the fact that paper is composed essentially of fibers, interlaced and matted together, leaving innumerable holes for the molecules of water vapor and air to pass through by diffusion or molecular movement. The metal container presents a continuous barrier to the bombardment of these molecules, except where the joints are open and protect against the diffusion of gases in proportion to the tightness of the seams.

Paper of various kinds is extensively used as a lining material for bags, cases and cans of many kinds. Here it serves to prevent contamination from extraneous dirt and to prevent loss of finely divided food products. Often paper liners are made water proof to add to the protective value of the outer container or to preserve the moisture content of the product. Greaseproof papers

also are used to prevent the escape of oils and fats from such products as nuts, biscuits, etc. Paper liners have found extensive application as liners for metal cans on account of their insulating value and ability to absorb water which may condense on the walls of the container in spite of its insulating properties.

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CHAPTER XVI

PRACTICAL APPLICATION OF FOOD PRESERVING PRINCIPLES

Collection of Preliminary Data—Study of Product—Selection of Preservation Methods—Time Tests.

Now that we have completed our discussion of the food preservation principles it may be of service to point out some of the ways in which a knowledge of these principles may be put to practical account. It is obvious that a knowledge of the fundamentals of the subject will be of great general benefit to anyone whose livelihood is gained from the food industry. It may not be so apparent, however, that close application of these general principles may be put to immediate practical use in the development of new products and processes and in the improvement of old products and methods that are now in practice.

Before deciding which methods are best adapted for the preservation of a product the food technologist must consider many other questions not directly related to preservation. He must consider the cost and probable selling price. He must consider whether the product is a staple necessity or a luxury and whether it is bought in large or small quantities. Having decided that there is a definite market for the article and the details of his

marketing plan he is then ready to go into the question of perfecting the keeping qualities of the product itself. Before the advent of scientific development methods the product was developed first and the marketing planned afterwards. It is now becoming apparent to manufacturers that a new product or improvements in old products may be developed as surely as new machinery is built in modern shops and that if there is a need for a new food product in a certain field, it is only necessary to expend the required amount of well directed effort and the product will be forthcoming.

Assuming that the product itself and the form in which it is to be presented to the public have been decided upon the problems of actual preservation are to be faced. At this point the most careful consideration must be given to the chemical and physical composition of the food. The exact percentage of the principal constituents, the fats, proteins and carbohydrates are of small importance compared with the percentage of moisture, the amount and composition of soluble matter dissolved in the water, the amount of water, soluble acids, etc. The presence of volatile flavoring oils or fixed oils which are subject to rancidity must be taken into account and the proper protection provided. Physical changes due to temperature fluctuations and other causes must always be kept in mind. Observation and study cannot be carried too far in these respects. A few hours of study and effort spent in learning every detail of the physical and chemical composition of the product to be preserved may save months of time and enormous financial loss on account of spoilage.

With the full knowledge of the composition of the product the possibilities of damage by the various causes of spoilage may be gone over one by one and a fairly accurate prediction with regard to the amount of trouble which may be expected from each. The next step is to select the preserving method or combination of methods which have the ability to counteract the cause of spoilage to which the product is subject.

The following rules, while subject to many exceptions, will assist in arriving at the correct preservation process.

1. Dry foods, consisting essentially of proteins and carbohydrates and comparatively free from hygroscopic or water-attracting substances require protecton only from animal pests and insects. Properly selected simple storage is usually sufficient.

2. Dry foods containing fats or hygroscopic substances must be kept at reduced temperatures or in hermetically sealed containers to protect from atmospheric damage.

3. Susceptibility to spoilage increases with an increase in water content.

4. In foods containing high percentages of water, the presence of soluble matter in solution in the water decreases susceptibility to most spoilages.

5. Susceptibility to spoilage increases with an increase in the temperature of storage.

6. Foods containing large percentages of water must

be sterilized by heat, chemically preserved or held at low temperatures for preservation for more than a few days.

7. Acid foods are more easily sterilized by heat than neutral or slightly alkaline foods. The difficulty killed bacteria, the spore formers, cannot develop in the more acid foods.

While the principles of food preservation which we have discussed will be of the greatest assistance in arriving at practical new preserving processes or in improving those already in practice we cannot hope to displace the most reliable of all tests, the test of Time. We can, however, save a great deal of time by being able to predict the kind of spoilage that is likely to cause trouble and to guard against this trouble by selecting the best means of preservation against it. Then when we are ready to make our time tests we can be satisfied that the fundamentals of preservation have been observed and that we need expect only minor changes which can readily be prevented.

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